Senator George J. Mitchell Center
Annual Technical Report
FY 2014

Introduction

The Maine Water Resources Research Institute is the primary independent source of water resources research in the state. With a focus on sustainability, we facilitate the advancement of water science in the state by supporting research, graduate studies, and outreach. Maine is fortunate in being a water-rich state with extensive surface water and groundwater resources. These water resources are essential to the regional economy in terms of tourism, industry, and ecosystem services. The state is not without water resources concerns due to spring flooding, sea-level change, urbanization, stormwater, endangered aquatic species, harsh winters, and natural contaminants such as arsenic in drinking water. It is our mission to facilitate the process to identify, understand, and solve the problems encountered by resource managers.

The federally authorized Maine Water Resources Research Institute provides fundamental and essential functions, none of which would exist without explicit Congressional re-authorization and appropriations. The federal money that supports the Institute is highly leveraged with other funds provided by stakeholders, universities, and researchers. In order to address key problems in the best way possible, research project proposals are evaluated by peer-review and approved by our Research Advisory Board composed of members from the U.S.G.S. Water Science Center, State Environmental Agencies, academia, and industry. During the FY14 period, the Maine Institute supported two (2) research projects, with prominent student involvement: (1) Analysis of phosphorus cycling control of gleotrichia in a public water supply lake; and (2) Assessing effects of changing climate on landscapes, the generation of sediments in low-order drainages and connections to lake water quality. The Institute supported additional Information Transfer activities such as working with municipalities to manage road salt to protect water quality, the Maine Water Conference and groundwater education in rural communities (GET WET!) activities. These projects directly provided support to two graduate students and involved several undergraduate students in a variety of roles.

The Maine Institute Director, John Peckenham, also serves as the Associate Director of the Senator George J. Mitchell Center for Environmental and Watershed Research. The Mitchell Center provides the administrative home for the Water Resources Research Institute. The broader mission of the Mitchell Center enhances our efforts to have the Maine Institute increase the breadth and accessibility of water research in Maine. The Mitchell Center is the recipient of a five-year EPSCoR grant from the National Science Foundation to develop the Sustainability Solutions Initiative. This grant is fostering even greater multi-institutional interdisciplinary research, including several projects related to water resources.

The 20th annual Maine Water and Sustainability Conference was held in March 2014 and continues to be the leading regional event for the water community. The conference attracted more than 300 registrants. The number of people and organizations who support and contribute to this conference reflects the importance of water to the people of the State of Maine. Through the hard work of Institute staff, the Conference Steering Committee, and other key supporters, we have been able to address the important water issues in Maine and to bring together diverse interest groups. In October 2014, the Maine Institute co-sponsored the Northern Maine Children's Water Festival. Several hundred sixth-grade students converged on the University of Maine to take part in hands-on activities, quiz shows, and demonstrations involving water in Maine.

The Water Resources Research Institute's affiliation with the Mitchell Center gives us the ability to support both large and small projects that address important local needs. It also provides us leverage to develop and attract funding from other agencies. In FY14, the Maine Institute had projects that brought in other funds and contributions from state agencies (e.g. Department of Environmental Protection), federal agencies (e.g. Fish and Wildlife, Environmental Protection Agency, National Oceanic and Atmospheric Agency), and foundations. None of these projects would be possible without the support of the federal Water Resources Research Institutes program and the U.S. Geological Survey.

Research Program Introduction

The Maine Water Resources Research Institute supports research, information transfer projects, and seed grants using 104b funds. Grants funded under Section 104b deal with important aspects of Maine's highly-valued water resources. Projects are awarded on a competitive basis using a two-stage selection process. The Research Advisory Committee, comprised of the Institute Director, Regional U.S.G.S. Chief Scientist, State and Federal Agencies representatives, and Water Resources Professionals, set the research priorities based on current state needs and issues. The Institute issues a call for pre-proposals in the spring. The pre-proposals are reviewed by the Executive Committee (5 individuals) and full proposals are solicited for 150% of available funds. Full proposals are sent out for external review with out-of-state reviewers required. The full Research Advisory Committee (12 members) reads the proposals and reviews to provide the Institute Director with a ranked selection of proposals to fund. Much effort is made to solicit suggestions for themes, to diversify the types of projects funded, and to include researchers from the small colleges and universities in the state. Preference is given to support new faculty and projects developed by students. Investigators are encouraged to collaborate with state and federal agencies and to seek additional contributions for their projects.

Optimized Pre-Treatment for Fluorescence Monitoring of Surface Fresh Water Contamination

Basic Information

Title:	Optimized Pre-Treatment for Fluorescence Monitoring of Surface Fresh Water Contamination
Project Number:	2013ME293B
Start Date:	3/1/2013
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	2nd
Research Category:	Water Quality
Focus Category:	Methods, Models, Water Quality
Descriptors:	None
Principal Investigators:	Howard Patterson, John Cory Ahern, Gregory Hall

Publications

1. Ahern, John C., R. Fairchild, T. Jin-Sun, J. Carr, H. Patterson, 2015. "Photocatalysis of Pharmaceuticals Over BiOX Catalysts (where X= Cl or I)."Applied Catalysis B: Environmental. (Accepted)
2. Ahern,J. , M.Theriault, N. Caputo, J. Killarney, H.Patterson. 2014. Rapid Detection of Hormone and Petrochemical Contaminants in Natural Water Systems. Poster, Maine Sustainability & Water Conference, Augusta, ME
3. Ahern, John C.; Patterson, Howard H.; Kelly, Andrew, W.; Pike, Robert D. "Sodium and Terbium Chlorobismuthate(III) Salts: Synthesis, Structure, and Photocatalytic Behaviour." Dalton Transactions. (revisions under review 5/4/2015)
4. Ahern, John C.; Fairchild, Rebecca; Thomas, Jin-Sun; Carr, Jordan; Patterson, Howard H. "Photocatalysis of Pharmaceuticals Over BiOX Catalysts (where X= Cl or I)." 249th ACS National Meeting, Denver,CO.
5. Ahern, John C.; Patterson, Howard H.; Kelly, Andrew, W.; Pike, Robert D. "Sodium and Terbium Chlorobismuthate(III) Salts: Synthesis, Structure, and Photocatalytic Behaviour." 249th ACS National Meeting, Denver,CO.

Final Report:
Project title: Optimized Pre-Treatment for Fluorescence Monitoring of Surface Fresh Water Contamination.

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Note: Two related papers have come out of this research. (1 is accepted and the revisions for the other are under review)
1. Ahern, John C**.;** Fairchild, Rebecca; Thomas, Jin-Sun; Carr, Jordan; Patterson, Howard H. "Photocatalysis of Pharmaceuticals Over BiOX Catalysts (where X= Cl or I)."*Applied Catalysis B: Environmental*. (Accepted 4/14/15)
2. Ahern, John C.; Patterson, Howard H.; Kelly, Andrew, W.; Pike, Robert D. "Sodium and Terbium Chlorobismuthate(III) Salts: Synthesis, Structure, and Photocatalytic Behaviour." *Dalton Transactions*. (revisions under review 5/4/2015)
These papers are included as separate files.

John also presented the material covered in both of the above papers in a presentation at the 249th ACS National Meeting in Denver in March 2015. The abstract has been included as a separate file.

Also, The start of this project was delayed until Sept. 1st 2013 so the 12 month timeframe for experiments ends August 31st 2014. A no-cost extension was filed to allow funds to continue to be used until 2/28/15.

I. Problem and Research Objectives:

A. *Problem:*

Disasters like the Deepwater Horizon oil spill and the cost of its cleanup have served as a hard lesson for public and private research centers as well as the petroleum industry to develop new response technologies to prevent impact to the environment. Such large spills are infrequent but thousands of smaller spills occur every year. Nearly 20,000 oil spills are reported to the EPA annually.[1–4] Most of these spills are from overfilled fuel tanks and overturned tanker trucks, some of which enter fresh water sources including one in Maine during March 2011 when a tanker overturned and spilled over 1000 gallons of diesel into the Pleasant River endangering a local salmon hatchery.[5,6] Phenol is just one of the many toxic compounds in refined fuels.[7,8] A rapid means of quantification of phenol and other petroleum contaminants is necessary.

A wide variety of personal care product and pharmaceutical (PPCP) contaminants are being detected in natural water sources around the world. There is a growing body of scientific literature demonstrating the extent of the problem; from antidepressant pharmaceuticals being found in fish tissue to anticonvulsants in our drinking water.[9,10] The synthetic estrogen 17α ethinyl estradiol (EE2) is now ubiquitous in waterways and has been found to negatively affect fish reproduction.[11] Estrogen mimics similar to EE2 have been linked with decreased fertility rates and increased incidence of reproductive organ cancer in humans and wildlife.[12]

EPA water detection methods, mainly gas chromatography-mass spectrometry (GC/MS) and liquid chromatography-mass spectrometry (LC/MS) can detect small concentrations but involve a great deal of time and resources as well as produce relevant amounts of hazardous waste. There will always be a market for the traditional highly accurate methods of trace contamination but for most purposes a novel, cost effective and more sustainable method is needed. Current methodology for identifying pollutants in natural water supplies is costly and can take several weeks to generate full results. In comparison, luminescence spectroscopy combined with PARAFAC statistical analysis is rapid and less expensive in both personnel time and equipment. The potential time and cost benefit of the proposed method will allow for more frequent sampling and allow for the assessment of a wider range of potential contaminants to provide a more accurate analysis of water quality. The ability to quickly and cost-effectively quantify contaminants of concern in water supplies has far reaching implications from public health in the third world to national security. The Patterson group among others have had success in discriminating pollutants in environmental samples around the ppm level using excitation emission (EEM) followed by PARAFAC analysis.[13–15] The goal of this research is to develop an screening process for quantifying water borne pollutants using luminescence/PAFAFAC analysis. This effort fits well with the Maine WRRI initiative of protecting fresh water supplies.

C. Research Objectives:

-Develop screening methods for single pharmaceuticals/PPCPs including EE2, estriol, mestranol, sulfamethoxazole and ibuprofen as well as the petrochemical phenol. These studies are to be conducted in a variety of water types including deionized water, deionozed water spiked with dissolved organic carbon as well as natural river water.
-Adapt the methods to allow for discrimination of compounds in complex mixtures of similar substances. Natural waters contain mixtures of closely related chemicals so it is essential to be able to discriminate between them.
-Compare limits of detection(LOD) for screening method to those published by the EPA using GCxMS/LCxMS.
-Provide a cost benefit ratio of the limited pretreatment plus EEM/PARAFAC analysis to the full pretreatment and GC/MS EPA method.

II. Methodology:

A. Sampling:

The research started with selecting water sources. Deionized (DI) water was used as the medium to start with because it would provide the cleanest spectra. Next solutions of DI were spiked with 10ppm(10mg/L) of either standardized fulvic, humic or Suwannee River composite DOC. These solutions mimic a natural system while being able to control the variety and amount of interfering components. Finally, Stillwater River water was collected in Orono Maine and tested a medium. Phenol is dissolved directly into the natural water solution. Similar less water soluble petrochemicals could be brought into solution using the method developed by Stelmaszewski et al. (2011) for no.2 oil.[16] EE2 and the other pharmaceuticals were dissolved in the collected water at environmentally relevant concentrations. Solution pH was monitored for any changes after the compounds were added.

B. Pre-treatment:

EPA pre-treatment methods were carried out in their entirety including solid phase extraction and liquid/liquid extraction on spiked samples with environmentally relevant concentrations of the pharmaceuticals and phenol contaminants in river water to test for detection limits using GCxMS. (EPA method 8270D for phenol and method 1698 for EE2.) Solvent phase extractions were also evaluated as a means to decrease the LOD for our fluorescence/PARAFAC based screening methods. The objective our developing new fluorescence based methods is to limit the need for such costly and environmentally hazardous methods.

C. Detection and Modeling

Fluorescence spectroscopy was used to determine the identity and concentration of compounds in solution. Fluorescence spectroscopy is an efficient method of analyzing samples because it requires very time and has needs only limited sample preparation. The resultant emission wavelength can be highly indicative of certain groups of compounds and relative intensity among samples can help gauge concentration.[14] The researchers used a Jobin Yvon Horiba Fluorolog fluorometer with accompanying Fluorescence software. The PARAFAC analysis was done on John Ahern's and Jim Killarney's licenses of Matlab-based PLS toolbox from Eigenvector Inc.

One-dimensional fluorescence was taken for each sample via a process called synchronous scan fluorescence spectroscopy. (SSFS) Simple excitation or emission scans hold either the emission or excitation wavelength constant as collect signal for the other variable. Synchronous scan works in a different fashion where the excitation and emissions are collected simultaneously. This is possible by setting a constant difference between the collected excitation and collected emission. This difference is referred to as $\Delta\lambda$. Given a delta lambda of 25nm and a spectral range of 300-500nm the excitation scan runs from 300-500nm and simultaneously the emission scan is collected from 325nm-525nm. The rate of the simultaneous scans is kept constant so the emission scan is always observing at a wavelength 25nm higher than the excitation scan so there is no problem with scattering. This method is very rapid however it requires the time and expertise to differentiate excitation signals from emission signals and the ideal $\Delta\lambda$ can be difficult to find for complex solutions.

Two-dimensional fluorescence of each sample were taken by scanning the excitation wavelength and recording the emission wavelength and intensity at each excitation. This data is commonly referred to as an excitation emission matrix(EEM) and it provides a three-way data set of excitation, emission and intensity. The EEM is still considered bilinear because intensity is a dependent variable. Due to their bilinear nature, fluorescence EEMs can be analyzed using PARAFAC analysis and other multi-way chemometric methods.[17]

EEMs were taken by passing light from a xenon lamp through a cuvette of sample and detecting the fluorescence reading. In EEM spectroscopy excitations are run at given increments (1-5 nm) and the emission spectra are collected for each. Once the given excitation range has been run the computer composes a matrix of excitation vs. emission vs. intensity in photon counts per second. 3-D spectra can be rendered from this with excitation on the y axis, emission on the x and intensity on the z axis. See an example in figure 1 below of EE2 spectra the group

collected. Alternatively a color-coded 2-D image can be made with intensity being indicated by the color providing contours much like those in a topographic map.

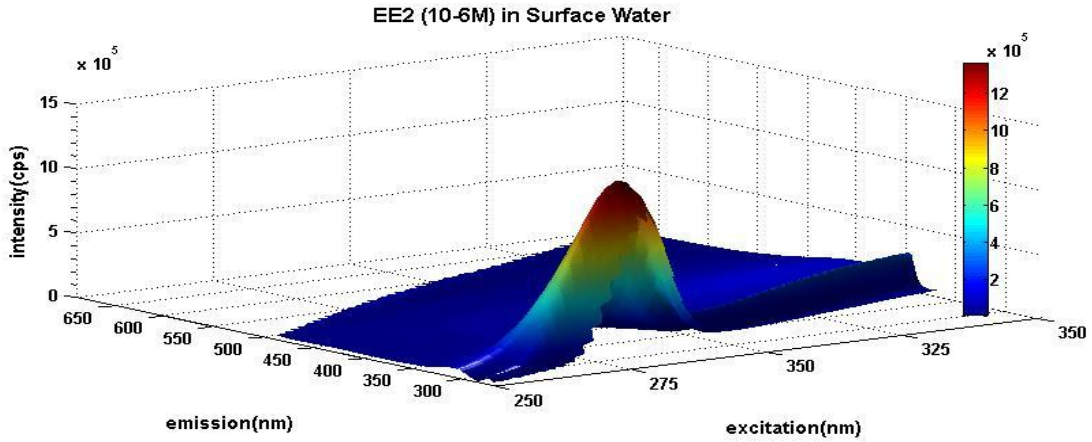


Figure 1: EEM spectra collected of 17α-ethinylestradiol spiked in natural water samples at $4.6x10^{-6}$M (1.4mg/L)concentration.

These spectra are helpful in qualitative judgments but cannot be used directly to make quantitative analyses nor can their matrices without the proper software. The problem is especially severe because natural water samples have so many types of compounds in them that have overlapping characteristic signals (in this case excitation/emission wavelengths). The same problem arises for other characterization techniques like overlapping retention times and fragmentation patterns in GCMS data. PARAFAC analysis can process the matrices allowing for separation of signal overlap and account for energy transfer processes like quenching.[14]

PARAFAC analysis is used to help deconvolve spectral data so that specific compounds can be measured in matrix. The primary advantage of using PARAFAC for the proposed work is not having to measure the standard spectra of every contributor to fluorescence within the spectra in order to determine the contributions of all the factors. This consideration is particularly useful when analyzing samples of complex mixtures where standard solutions of the components are unavailable. PARAFAC is able to take advantage of the bilinear nature of EEM spectroscopy. This advantage allows the researchers to utilize EEM spectroscopy where fluorescence emission spectra are taken at many different excitation wavelengths so signals from multiple different compounds can be observed. PARAFAC studies have been published by the Co-PI: Gregory Hall for compounds in oil.[18],[19] Both of these methods could be coupled with more conventional analysis of chromatographic data by Principal Components analysis, and therefore show the correlation between spectral and chromatographic results.[20] While chromatographic techniques exist that can address these issues, they can be cost and time prohibitive; therefore, a spectral validation of the pollutant levels in water is needed. This is extremely important in rural sites where responders may not arrive before the pollution impacts the waterway. The software proposed herein performs all the above methods.

GC-MS and LC/MS are the industry standards for the pollutants in question. No other technique is as reliable for trace analysis. GC-MS spectra were collected on a Hewlett-Packard 5890 Gas Chromatograph with a Hewlett Packard MSD 5970 as a detector. A 30mx.25mm ID DB-5 MS column was used. EPA method 8270D is useful for a wide range of semi volatile

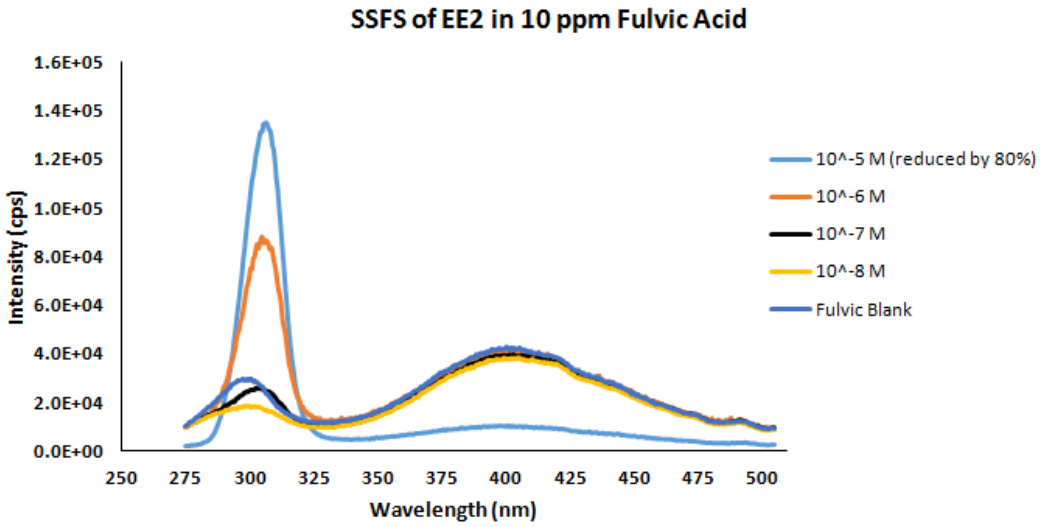
organics including the petrochemicals since the pollutants selected are usually found in a blend of other semi volatiles like diesel fuel. This method has detection limits of 10µg/L(10ppb) for Phenol. EPA method 1698 covers a broad range of steroids and personal care products and was used for EE2 to give a detection limit of 2ng/L (2ppt). The same method will be used for other pharmaceuticals including estriol, mestranol, sulfamethoxazole and ibuprofen.

III. Principal Findings and Significance:

A. Detection Limits:

Synchronous Scan Fluorescence Spectroscopy (SSFS) Limits of Detection: Limits of detection were determined for EE2, IBU and SUL in de-ionized water and three different dissolved organic matter (DOM) types, Suwanee humic acid, Suwanee fulvic acid and a Stillwater River sample. In de-ionized water, EE2 has a limit of detection(LOD) of roughly 10^{-9} M (296ng/L/296ppt).

The quantum yield of fluorescent compounds (photons emitted/incident photons) as well as spectral overlap of signals both have a strong impact on the limit of detection. DOM can interfere with the ability to discriminate the EE2 signal in luminescence spectra. This is because of fluorescence quenching between EE2 and DOM as well as an overlap of the luminescence signals between the two species. Figure 2 shows varying concentrations of EE2 in a 10 ppm fulvic acid solution. The fulvic acid peak is broad and shows a maximum at roughly 400 nm. It is an unresolved peak that runs from 300 nm to 500 nm. The water Raman scattering peak is also very visible at around 300 nm. In a fulvic acid aqueous solution, the EE2 peak is clearly visible at 10^{-6} M (296µg/L/296ppb) concentration because of its high quantum yield, EE2 ($\phi = 0.067$)[127]. However, it is inseparable from the water scattering peak and tail of the fulvic acid peak at a concentration of 10^{-7} M. (29.6ppb)



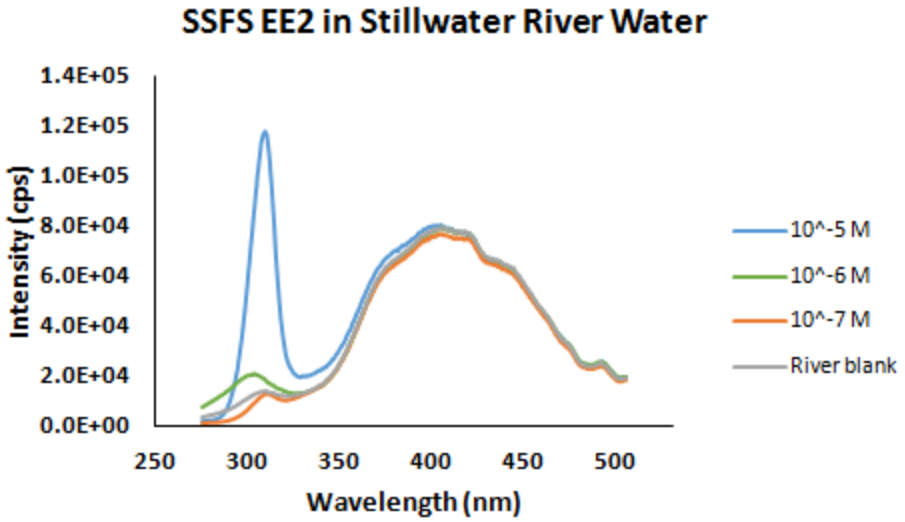


Figure 2: SSFS of EE2 at varying concentrations ($\Delta\lambda$ = 29 nm, emission wavelength) in Fulvic acid DOM and Stillwater River samples.

Just like with fulvic acid, the LOD for EE2 is significantly higher when in both humic acid and Stillwater River samples compared to de-ionized water. The LOD for samples spiked with humic acid had similar LODs to those with fulvic but was marginally lower for the Stillwater River sample.

Ibuprofen has a much lower quantum yield than EE2 at similar concentrations (ϕ = 0.056)[128] . This makes detection using SSFS more difficult. However, its peak is further from both the DOM background. Its LOD is between 10^{-7} and 10^{-8} M in de-ionized water. Its peak is well separated from DOM so there is not as much loss of LOD when compared to EE2 as peak overlap is much less. The LOD for IBU in all three DOM type samples was roughly 10^{-6} M. Because of its wavelength distance from the DOM source, IBU experienced a 10 fold increase in its LOD. A 100 fold increase in LOD was observed for EE2 when DOM was added because it is significantly closer to the DOM peaks. Additionally, EE2 is a slightly more hydrophobic compound than IBU (K_{ow} EE2 = 4.15, K_{ow} IBU = 2.48) so more quenching of the hydrophobic fractions of the DOM occurs.

Sulfamethoxazole is a compound that shows strong fluorescence; however, its synchronous scan emission maximum is at a higher wavelength than the other two PPCPs studied and thus more overlap with the DOM peak is expected. In de-ionized water, emission signal was observed above background at a 10^{-8} M concentration level. When spiked in DOM samples, the LOD was lessened to 10^{-6} M concentrations levels.

EEM/PARAFAC Limits of Detection: PARAFAC models based on EEM data were created to detect EE2 in de-ionized water, fulvic acid and Stillwater River solutions. The LOD for EE2 in de-ionized water using PARAFAC treated EEM data was found to be between 10^{-9} and 10^{-10} M. Figure 3 displays the relationship between the PARAFAC score value and the known concentrations. The score value refers to the value the PARAFAC model assigns to a single of

group of fluorescent factors. This value is designed to be proportional with the concentration of a single compound (as it is in this case) or a group of similar compounds for more complex solution analysis. The strong, linear relationship between the model assigned "score" and known concentration means that the model is an accurate predictor of concentration within the range studied.
This prediction curve is used to predict unknown concentrations loaded into the model.

Models for the fulvic acid and Stillwater River samples were constructed in the same fashion as the deionized water. The model is able to predict concentrations between 10^{-8} and 10^{-9} M in these water types. It is no surprise that the LOD is lower for the DI sample versus the DOM spiked samples since there are no other substances in DI to interfere with the EE2. The DOM profile of Maine rivers is mostly fulvic acid so it is expected that the results for the river water are very similar to the fulvic spiked samples[130]. A significant improvement in the LOD for EE2 (10^{-8} and 10^{-9} M) was observed when using PARAFAC modeling for detection compared to the SSFS alone method(10^{-6} to 10^{-7} M). EE2 emission wavelength overlaps the edge of the DOM signal and is difficult to measure at low EE2 concentrations. The ability of the PARAFAC to resolve overlapping signals greatly improved the limits of detection for EE2.

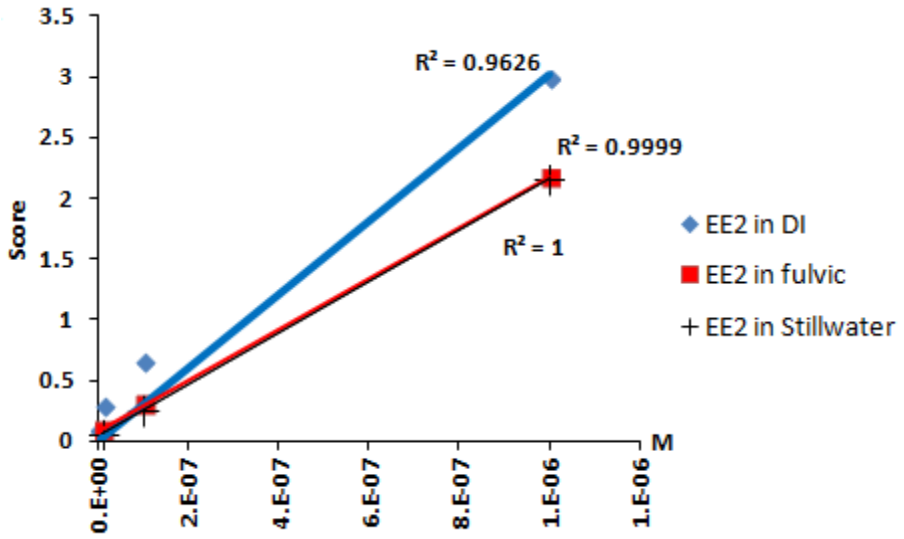


Figure 3 Beer's law plot for the ability of the model to predict sample concentration of EE2 in de-ionized, fulvic acid and Stillwater River aqueous samples.

Using the same modeling technique for ibuprofen detection, a LOD between 10^{-6} and 10^{-7} M was determined for both the fulvic acid and Stillwater River samples (figure 4). These were the same range of detection of the SSFS method so there was no added benefit of using the more involved PARAFAC procedure instead of SSFS. This is because the IBU peak is already so separated from the DOM signal.

Using the modeling technique for sulfamethoxazole detection, a LOD between 10^{-8} and 10^{-9} M was determined for both the fulvic acid and Stillwater River samples (figure 5). PARAFAC proved to be a useful tool as the LOD range was increased by a factor of ten when compared to SSFS methods. Sulfamethoxazole displays strong luminescence, however, it has considerably more overlap with DOM luminescence than the other compounds tested. There was

a improved LOD with sulfamethoxazole demonstrating the usefulness of PARAFAC to resolve overlapping spectra in EEMs.

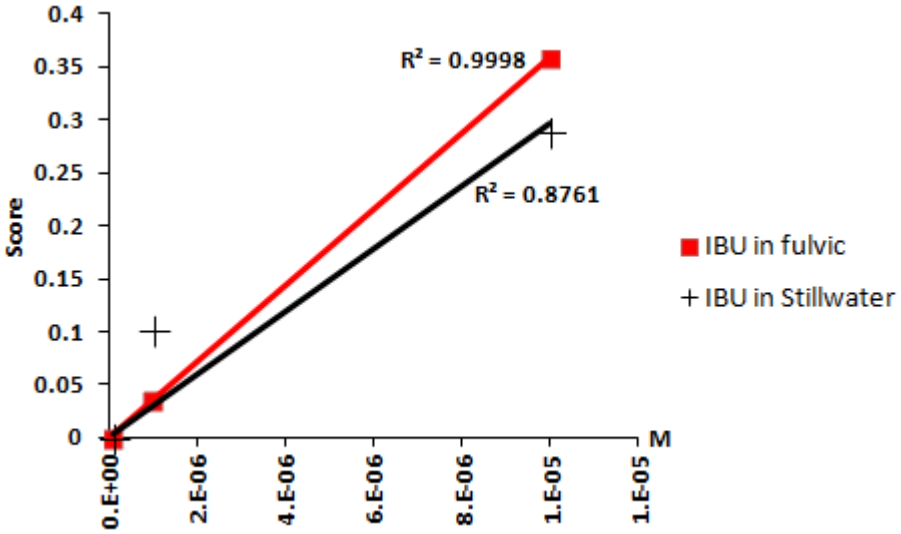


Figure 4: PARAFAC **s**core versus sample concentration for a model of ibuprofen in fulvic acid and Stillwater River aqueous samples.

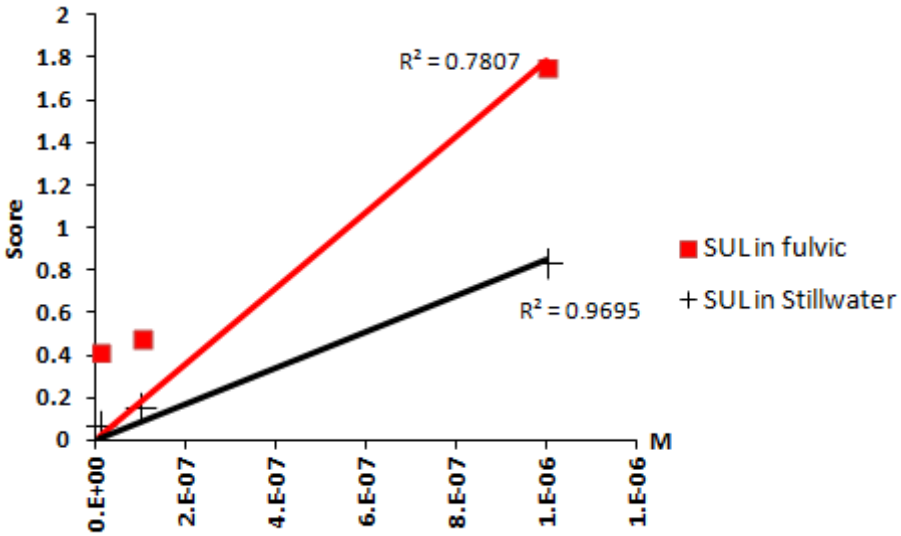


Figure 5: PARAFAC score sample concentration for a model of Sulfamethoxazole in fulvic acid and Stillwater River aqueous samples.

Chemical Extraction Prior to PARAFAC: Four different concentrations of EE2 (10^{-7}, 10^{-8}, 10^{-9}, 10^{-10} M) were extracted using $MeCl_2$, put through a roto-evaporator and then re-concentrated in MeOH. EEMs were taken from the extracted organic solution and modeled with PARAFAC. This procedure provides an LOD for EE2 somewhere between a 10^{-9} and 10^{-10} M concentration. Improved modeling and perhaps a larger concentration step could improve this result.

Nevertheless, these results are encouraging since the limits of detection of this simple procedure are approaching the detection limits for GC-MS based methods.

Table 1 summarizes the maximum detection limits in for the three different fluorescence procedures discussed. SSFS provides a limit of detection of 10^{-6} to 10^{-7} M for all three PPCPs in natural water samples. This level of detection would be appropriate for highly polluted sources or for methods where up-front separation, such as HPLC, is performed beforehand as LOD values for EE2 and SUL were considerably better in neat samples. Collecting EEMs of the samples and analyzing them with PARAFAC showed marked improvement for EE2 and SUL. Both of these compounds show strong luminescence and benefit from the spectral clarity that PARAFAC provides. When EE2 was extracted into a non-polar solvent and concentrated, the limit of detection was further improved. This method was easy to perform and was not costly from a material perspective. The limits of detection were comparable to more commonly used and more expensive methods.

Table 1 Comparison of limits of detection for 17α-Ethinylestradiol (EE2), ibuprofen (IBU) and sulfamethoxazole (SUL).

	PPCP (M)		
	EE2	IBU	SUL
Synchronous Scan	10^{-6}-10^{-7}	10^{-6}-10^{-7}	10^{-6}-10^{-7}
EEM/PARAFAC	10^{-8}-10^{-9}	10^{-6}-10^{-7}	10^{-8}-10^{-9}
Extraction/Concentration PARAFAC	10^{-9}-10^{-10}		

Table 2 summarizes the observed LODs for EE2 in each of the tested media via luminescence spectroscopy alone, luminescence with the aid of PARAFAC analysis and finally, extraction prior to luminescence and PARAFAC treatment after it.

Table 2: Limits of Detection for EE2 with just SSFS, w/ PARAFAC analysis, and w/ Extractions plus PARAFAC analysis.

Sample	**LOD for SSFS/EEM alone**	**w/ PARAFAC**	**w/ PARAFAC & extraction**
De-ionized water(DI)	10^{-9}-10^{-10}M	10^{-9}-10^{-10}M	10^{-10}-10^{-11}M
DI w/ fulvic acid	10^{-6}-10^{-7}M	10^{-8}-10^{-9}M	
DI w/ humic acid	10^{-6}-10^{-7}M	10^{-8}-10^{-9}M	
Stillwater River	10^{-6}-10^{-7}M	10^{-8}-10^{-9}M	10^{-8}-10^{-9}M

B. Ongoing Studies:
Detection Limit for Mestranol:

Mestranol has been dissolved in a variety of media including DI water, methanol, 50:50 mixtures of water and methanol as well as chloroform. In each case the optimal excitation is 285nm and the optimal emission is 297.5. This narrow $\Delta\lambda$ makes it difficult to pick out the compound in a spectra especially in complex solutions. Synchronous scan as well as EEM spectroscopy have been tried. The detection limit in the clean solvents (no DOC or other pharmaceuticals present) is roughly 5^{-4}M. Efforts to better discriminate mestranol are still ongoing.

Analysis of Mixtures of EE2, IBU and SUL:

The ability to discriminate individual pharmaceuticals from a mixture dissolved in water was tested. Deionized water as well as Suwanee River standard DOC doped DI water were used. The PARAFAC analysis of these studies is still ongoing. Results will be included in a forthcoming paper.

Limits of Detection of Phenol:

Synchronous scan as well as EEM alone was able to detect phenol in deionized water down to 4.3^{-7}M. EEM with PARAFAC were able to discern phenol in deionized water down to 1^{-7}M. This is the same limit of detection as the much more costly, time consuming and environmentally hazardous GC-MS method. Using fulvic, humic or Stillwater River water raised the LOD to 6.0^{-7}M for untreated and 2.0^{-7}M for PARAFAC treated samples. The PARAFAC analysis offered little benefit to the LOD because the phenol emission is at high enough energy(λ_{em}: 295nm) and has a high enough quantum yield to be well separated from the DOM peaks as seen in figure 6.(the DOM peaks cannot even be seen) These numbers are very close to the 1.1^{-7}M LOD for GCxMS. Considering the low LOD for the luminescence method it seems to be the obvious choice for detection of phenol. However, studies are still ongoing on mixing the phenol with similar petrochemicals. Many other compounds have a great deal of spectral overlap with phenol[21] and may have much higher quantum yields. It is expected that the LOD will be much improved using PARAFAC treatment of luminescence data for phenol detection in such solutions.

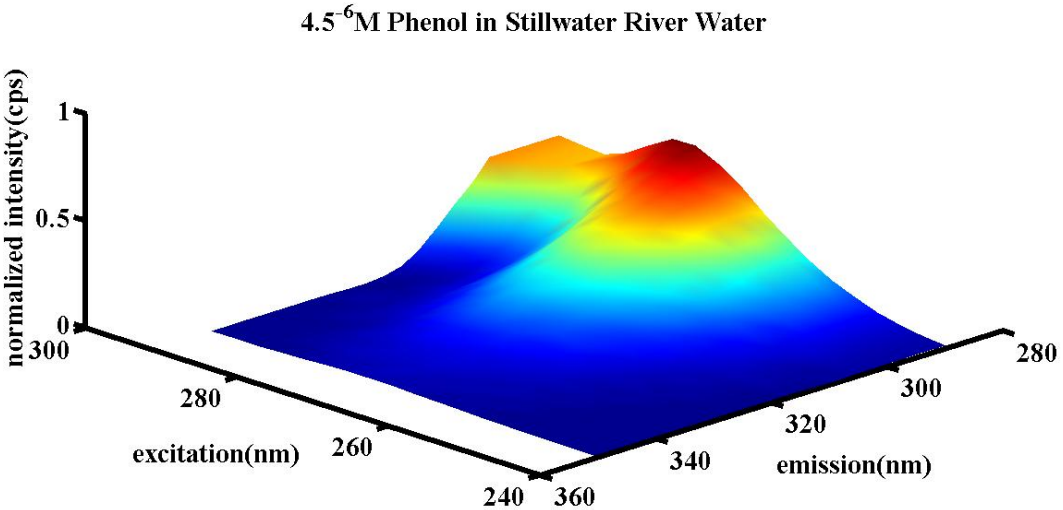


Figure 6: EEM spectra for 4.5^{-6}M Phenol in Stillwater River water demonstrating the ease of seeing phenol even in natural waters.

***C. Cost Analysis*:**
Obtaining GC/MS data via EPA Method #1698 takes approximately 4 hours including pre-treatment. The cost of the solvents, surrogate and fortifying solutions is about $40. As previously stated the detection limit is 1-10ppb for natural waters.

The PARAFAC analyzed EEM data took about 20 minutes to obtain and did not require any solvent or other solution expenses.

The capital costs of the EPA method are higher than the fluorescence setup and PARAFAC software especially when you factor in maintenance costs of the GC-MS as seen in the table below.

Table 3: Cost comparison between methods.

Category	Cost for GC/MS method	Cost for EEM/PARAFAC method
Instrument and software	**$60,000**	**$55,000**
Maintenance	$500+	0
Consumable supplies	$500+	0

C. Summary

Fluorescence Spectroscopy is an effective and low cost tool for detecting contaminants in natural water systems. We reached limits of detection comparable to those reached by more expensive detection methods. PARAFAC analysis aided in the detection process especially when the studying mixtures of different target compounds in solution. We were able to distinguish between the target compounds and other components naturally found in water like DOM. Lastly, doing liquid-liquid extractions prior to fluorescence further lowered limits of detection.

Supplemental Details:

A. Student Support and Training:

The gains of the proposed work go beyond publications. An essential part of this work is to give students the training necessary to become water resource professionals. The graduate student John Ahern and the two undergraduates Monique Theriault and Nina Caputo all participated in conducting the research. John and fellow group member Dr. James Killarney trained and oversaw the undergraduates in the use of the instruments and gave them the background information necessary to conduct the research. John is grateful to be supported with a stipend for his role in the research. John intends to submit papers to journals with the findings.

B. Achievements:

-Paper accepted for publication in *Applied Catalysis.*
-Paper in *Dalton Transactions* will likely be published pending acceptance of revisions.
-John presented the material covered in the *Applied Catalysis* and *Dalton Transactions* papers at the 249th ACS National Meeting in Denver in March of 2015.
-John successfully defended his PhD dissertation in April 2015 on the topics of the papers covered in the *Applied Catalysis* and *Dalton Transactions* papers, among other things.
-John Ahern presented at the Maine Water Conference in Augusta in April 2014.

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Partnership for Monitoring Maine Lake Temperatures in a changing Climate, Short-term Variability and Long-term Trends.

Basic Information

Title:	Partnership for Monitoring Maine Lake Temperatures in a changing Climate, Short-term Variability and Long-term Trends.
Project Number:	2013ME295B
Start Date:	5/15/2013
End Date:	5/14/2014
Funding Source:	104B
Congressional District:	second Maine
Research Category:	Climate and Hydrologic Processes
Focus Category:	Conservation, Ecology, Education
Descriptors:	None
Principal Investigators:	Daniel Buckley, Scott Williams

Publications

There are no publications.

Maine Water Resources Research Grants Program Summary Report

Partnership for Monitoring Maine Lake Temperatures in a changing Climate, Short Term Variability and Long Term Trends.

Dan Buckley, Chair, Division of Natural Sciences, University of Maine Farmington
Buckley@Maine.edu, phone 207-778-8151
Scott Williams, Executive Director, Volunteer Lake Monitoring Program

Problem and Research Objectives:

Temperature records over the last five decades have indicated that global temperatures have risen approximately 1^0F during that time and recently investigators have shown the impact that this is having upon attributes of aquatic environments such as ice cover and flow regimes of streams (Huntington et al, 2003) onset of ice cover and ice out (Hodgkins et al. 2005) and the epilimnetic temperatures of some of our largest lakes(Austin and Coleman, 2008). Lake water temperature data in Maine historically has been collected during water quality monitoring activities on a weekly or bi-monthly basis and as such are not very useful in examining long term trends. One exception to this is the data on water temperatures from the Lake Auburn intake pipe which are between 1 and 2^o C higher most months of the year than they were 50 years ago (data from Lewiston Auburn Water District). Recent lake temperature studies have dealt with a single lake or a few lakes at a time. Lake response to climatic changes (Heat budgets, mixing regime, thermal profiles, epilimnetic temperatures) may be mitigated by regional or local climate, lake size (surface area, maximum and average depth), elevation and geography. Maine with its many lakes and active volunteer monitoring program along with the development of inexpensive reliable water temperature monitors for season-long deployment presents a unique opportunity to monitor and analyze the effects of climate change on lake temperatures and thermal regimes in lakes with different physical dimensions and location attributes over time. This data collected annually will provide information on seasonal stratification and lake mixing regimes now and in the future. The importance of this long-term study cannot be overstated as we attempt to understand how the changing climate will impact nutrient cycles and lake productivity, dissolved oxygen concentrations, fisheries habitat, and ultimately biodiversity and aquatic species distributions.

Project Objectives:

- Increase the number of monitored lakes (currently between 25 and 30) in an ongoing long-term study where temperatures being logged every 15 fifteen minutes seasonally to between 40 to 50 lakes.
- Use the data in the analysis of long term trends and correlates with inter-lake variation among the lakes being studied.

- Use the data from specific lakes to examine daily fluctuations in temperature profiles and lake response to short term climatic changes.
- Provide this information to the Maine Volunteer Lake Monitoring Program and the Maine Department of Environmental Protection for dissemination to the public as appropriate and for the elucidation of emerging threats to water quality and lake ecology in Maine as lake temperatures change.
-

Methods: In a research program that began in 2007 seasonal water temperatures and light intensities in lakes are being monitored and logged every fifteen minutes by Hobo pendant data-loggers deployed at know locations in the spring by the UMF aquatic research team or our cooperating volunteers. Every temperature datum is time stamped and the all loggers are set to the same time regimen. The loggers are recovered in the fall and the data are downloaded and used in the calculation of average daily temperatures and elucidation of daily minimum and maximum temperatures. In most cases, a single data logger is placed in a lake at a depth of two meters, however in some lakes there are multiple loggers. In the latter cases the loggers may be buoyed in different parts of the lake at the same depth to look at horizontal location effects or multiple loggers are part of string designed to provide a record of changing vertical temperature profiles.

The WRRI grant allowed for the purchase of 49 additional Hobo loggers which have been used to add eight lakes to the study to date. In four of the lakes, Lake Auburn, Loon Lake, Round Pond and Middle Sandy River Pond, temperature profile strings with multiple loggers were deployed. In Lake Auburn the string was deployed last June and retrieved in November. In the other lakes the strings were deployed in the fall for retrieval this spring. In the other three lakes; Highland, Kezar, Pleasant, and Square Pond one or more loggers were deployed at 2m depth within 60 meters of shore. This past fall the summer's data is downloaded and stored along data from previous years and currently the data loggers are being readied for this year's deployment.

Principal Findings and Significance: While data has not been collected long enough to determine the impact of long term climate trends upon Maine lakes, the nuanced data provided by the loggers is very useful in elucidating lake temperature variability at depth, seasonal changes in temperature profiles and the near term impact of local weather upon lake temperatures and water movements. Figure 1 shows the 2013 summer profile for Lake Auburn. The figure shows the daily temperature variation by depth and that the variation appears to be the greatest between six and nine meters in depth. Given the diminished light intensity at these depths this variation appears to be the result of internal water movements, which is further backed up by the deviation of water temperature fluctuations from the solar signal as observed in Figure 2.

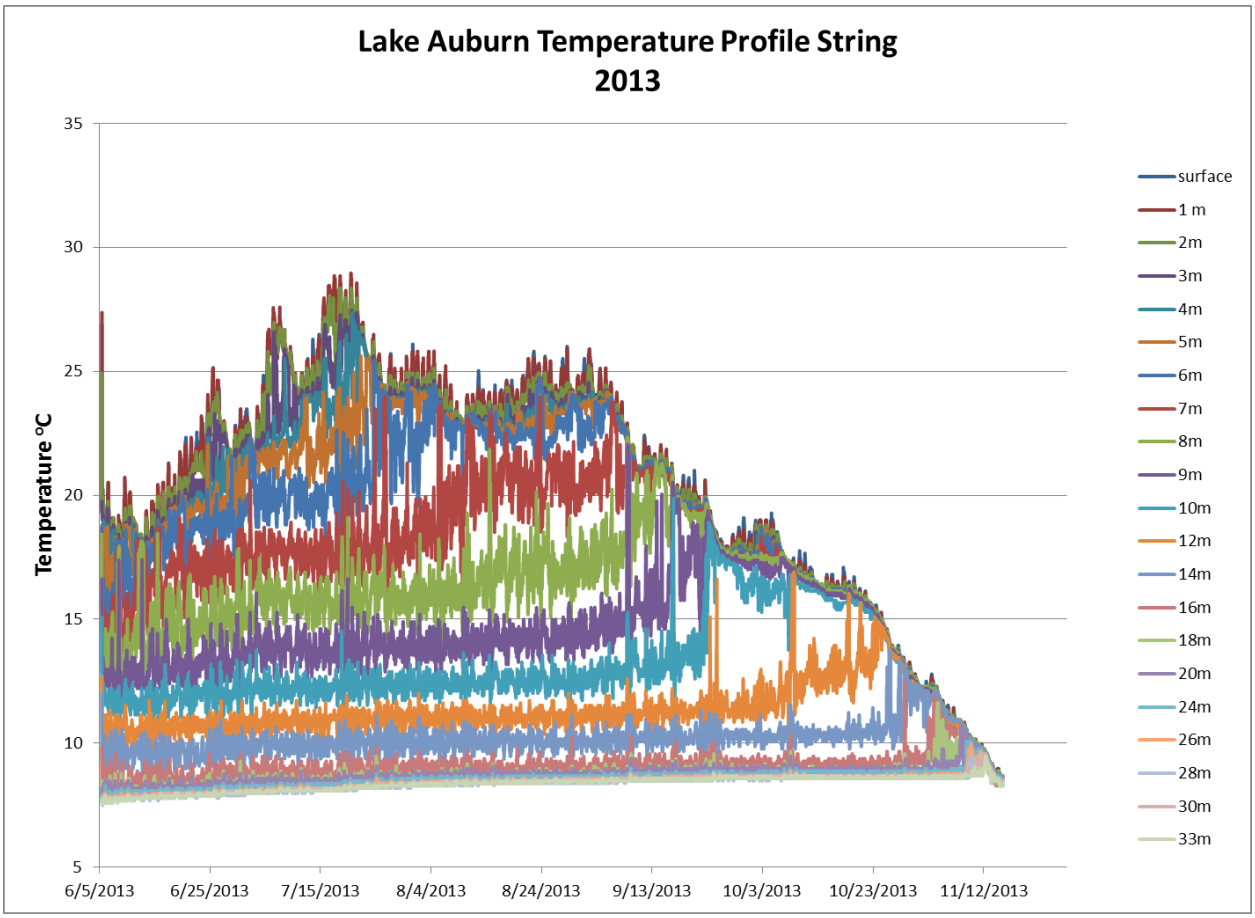


Figure1. Summer and fall water temperatures by depth for Lake Auburn, Maine.

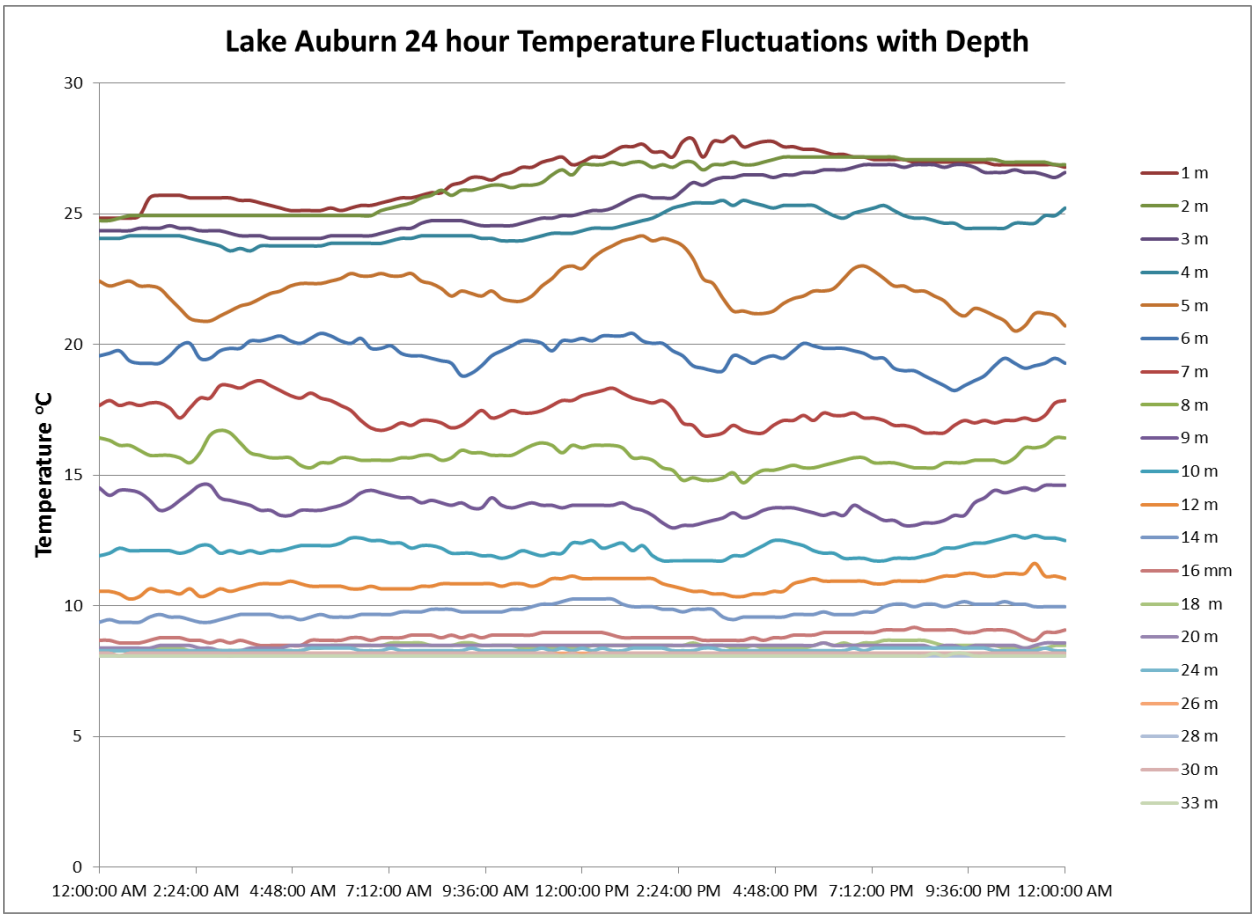


Figure 2. Lake Auburn temperature fluctuations by depth over a 24 hour period.

In Figure 3, The logger data from two different sites in Wilson Lake, Maine illustrates the effects of wind direction and water entrainment on water temperatures in medium sized lakes. At both sites the loggers are suspended at a two meter depth below the surface and the buoys are separated by about 2 km distance. The outlet to the lake is in the southeast corner of the lake with the major tributaries occurring on the Northwest shore. In general in Wilson lake water gains heat as it flows from northwest to southeast as shown by the data, however when the wind blows out of the south in some afternoons the entrainment of warmer surface water at the north end of the lake causes an upwelling of cooler waters at the south end of the lake and a reversal of the typical temperature differences between the two sites. This type of water movement is important in distributing heat in the water column as well as exchanging it with the sediments.

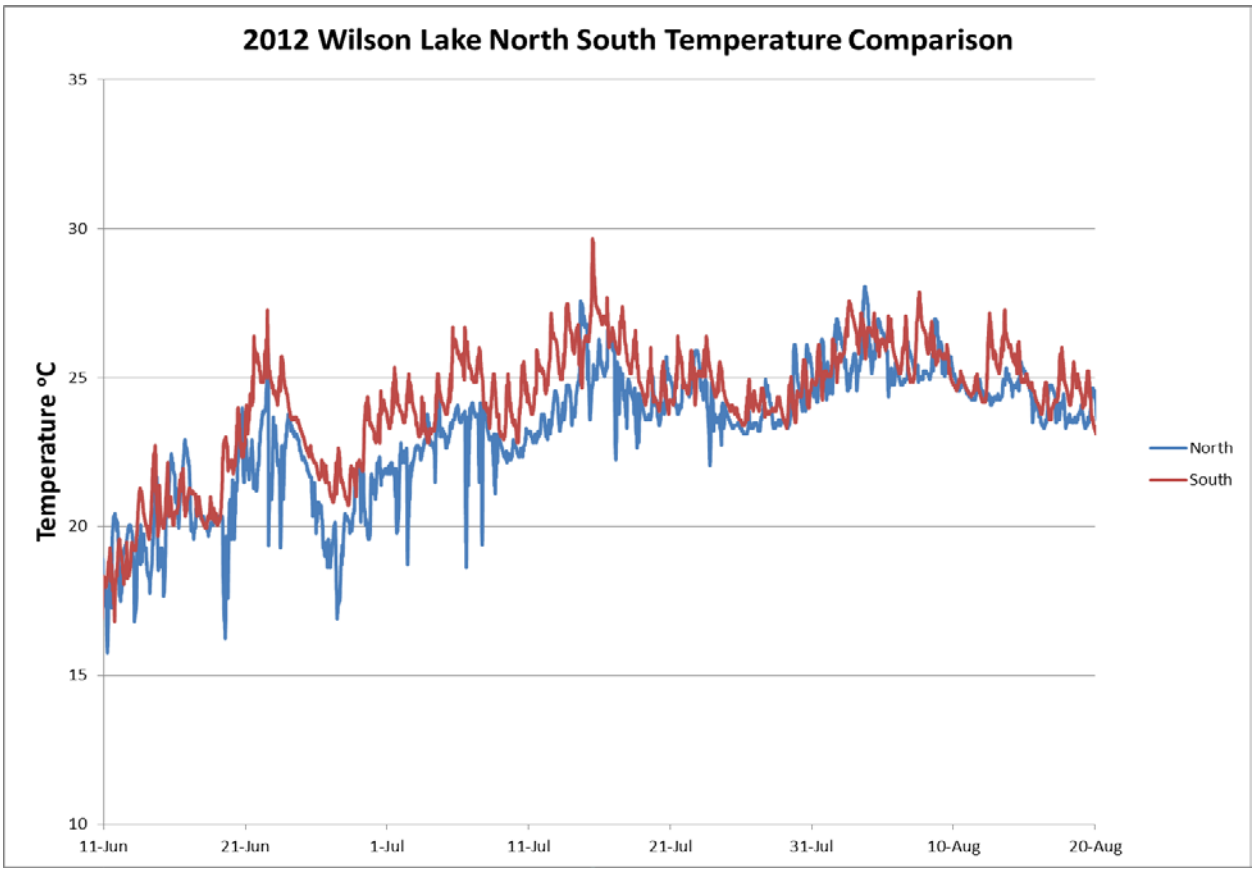
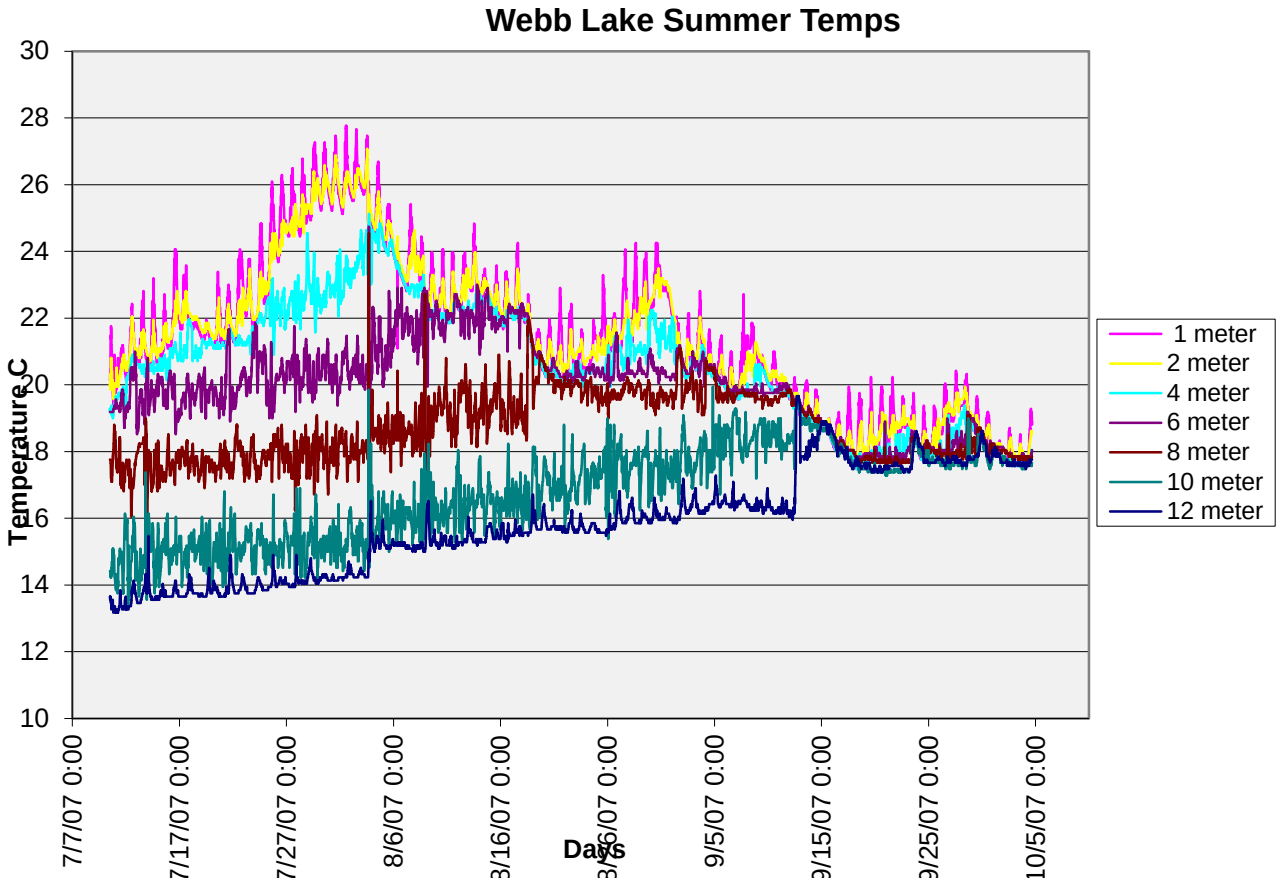


Figure 3. Wilson Lake temperature data recorded every 15 minutes.

In some cases local weather events and subsequent water movements are sufficiently strong to partially disrupt the thermal stratification and result in a sudden increase in bottom temperatures (Figure 4) as shown by the data from Webb Lake and a re-oxygenation of the hypolimnion as noted by the data from their VLMP volunteers.



Finally, continued use of Hobo loggers in monitoring lakes for the foreseeable future will provide a record of the long term effects of climate upon Maine's lakes thermal patterns and how such changes may impact other aspects of lake ecology.

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Controls of phosphorus cycling in Lake Auburn, Maine, USA: Spatial and temporal interactions among sediment, water column, and climate change

Basic Information

Title:	Controls of phosphorus cycling in Lake Auburn, Maine, USA: Spatial and temporal interactions among sediment, water column, and climate change
Project Number:	2014ME297B
Start Date:	4/1/2014
End Date:	3/31/2015
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Geochemical Processes, Hydrogeochemistry, Sediments
Descriptors:	None
Principal Investigators:	Aria Amirbahman, Linda Bacon, Stephen A. Norton

Publications

There are no publications.

Title: Controls of phosphorus cycling in Lake Auburn, Maine, USA: Spatial and temporal interactions among sediment, water column, and climate change

Project Number: 2014ME297B

Project Type: Research

Focus Category: Geochemical Processes, Hydrogeochemistry, Sediments

Descriptors: Phosphorus, Eutrophication, Geochemistry, Lakes, Water Quality

Start Date: 4/1/2014

End Date: 3/31/2015

Report to the Water Resources Research Institute

April 10, 2015

Submitted by Aria Amirbahman, Department of Civil and Environmental Engineering, University of Maine

In December 2013, a grant was awarded through the WRRI to assess the geochemical cause of algal blooms in Lake Auburn, a public water supply having a sensitive population of coldwater fish threatened by resultant high turbidities. It was envisaged that the results could inform decisions regarding future treatment strategies of the lake and provide an approach suitable for use in other Maine lakes and water supplies. The award amount was considerably less than what was required to conduct a thorough study, so we approached the Maoine Outdoor Heritage Fund (MOHF) and the Maine DEP for additional funding so that the project could move forward. At this time we have made considerable progress toward our objectives. We have a graduate student in a MS program who has been conducting most of the research and have learned much about the geochemistry of Lake Auburn.

Abstract of the project's results. We have determined that Lake Auburn sediment has very low concentrations of aluminum (Al) relative to iron (Fe) and phosphorus (P) with Al:Fe ratios ranging from 0.3 to 1.7 and Al:P ratios ranging from 2.0 to 14.5. Several studies, some of which include Maine lakes, have shown lakes sediments with molar Al:Fe ratios < 3 and Al:P ratios < 25 to be susceptible to P release under anoxic conditions. We sampled sediment from 11 locations in Lake Auburn. Our analyses show that Lake Auburn sediment is well below both the threshold of 3 for Al:Fe and 25 for Al:P (see figures next page), indicating that Lake Auburn may be vulnerable to internal P loading during summers with widespread hypolimnetic anoxia, as occurred in 2011 and 2012.

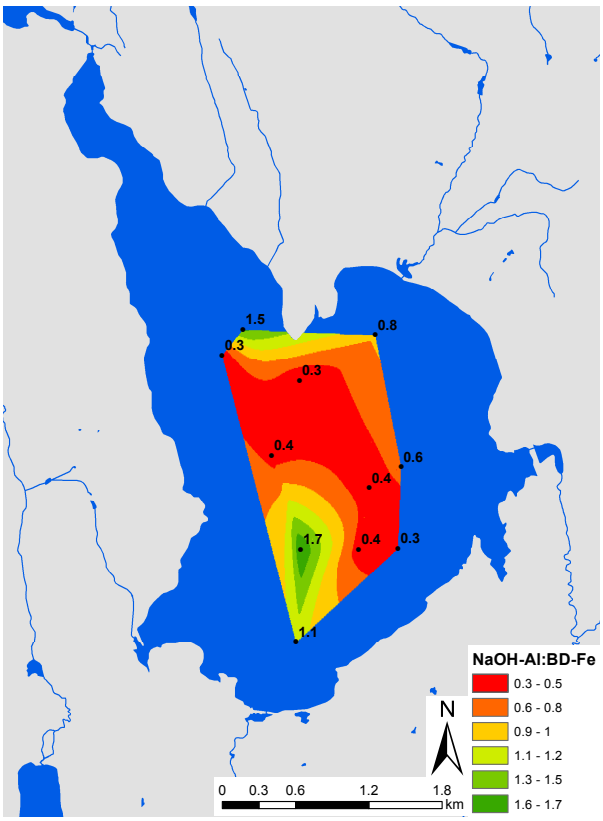
A survey of sediments from upstream lakes in the watershed (Mud Pond and Little Wilson Pond) showed that these lakes have more favorable Al:Fe and Al:P ratios with values >3 and >25, respectively. High concentration of Fe in Lake Auburn sediment may be linked to the presence the Basin and Townsend Brook wetlands. Water samples taken at several locations stretching from Mud Pond to Lake Auburn and from upstream Townsend Brook to Lake Auburn have shown an increase concentration of total Fe in both wetland systems. It is possible that the presence of these wetlands are causing an increased flux of Fe to Lake Auburn, which becomes incorporated into the sediments, making the lake at risk to internal P loading. However, it is also

possible that the presence of these wetlands decreases nutrient inputs (N and P) to the lake and, as such, it is important that the role these wetlands play in lake productivity is further evaluated.

Follow-up work. We are currently analyzing two 60 cm sediment cores that were extracted from Lake Auburn in March 2015. These cores are being dated using radioactive isotopes (^{210}Pb) and chemically analyzed to determine if there have been changes in sediment chemistry over the last several hundred years. We hope to determine any differences in sedimentation to Lake Auburn as land use within the watershed changed from agricultural to forested and if the emplacement of the dam, which created the Basin wetlands, has had a significant impact on sediment Al:Fe in the lake.

Presentations related to the project. The results of this study have been presented at the Oklahoma State Student Water Conference (March 2015, Stillwater, OK), the Maine Water and Sustainability Conference (March 2015, Augusta, ME), and the New England Water Works Association annual meeting (April 2015, Worcester, MA). The results from this study will also serve as the basis for the MS thesis in Civil and Environmental Engineering for Ms. Heather Doolittle at the University of Maine. She expects to graduate in December 2015.

Color photographs or figures related to the project. The following figures were included in the presentations made by Ms. Doolittle over the last few months. Contour maps of Lake Auburn surficial sediments show the Al:Fe ratios (left) and Al:P ratios (right). Both maps highlight the low concentration of aluminum relative to iron and phosphorus in the sediment. Photographs below the maps were taken while obtaining sediments from Lake Auburn. The first photograph illustrates use of a gravity coring device to obtain surface sediments (summer 2014), and the second photograph shows a deep core obtained in March 2015 which was collected by drilling through the ice using a Davis-Doyle coring device. The sediments at the bottom of the deep core were likely deposited around 500 years ago. As mentioned above, we are presently working to characterize the age and chemical/physical makeup of these sediments.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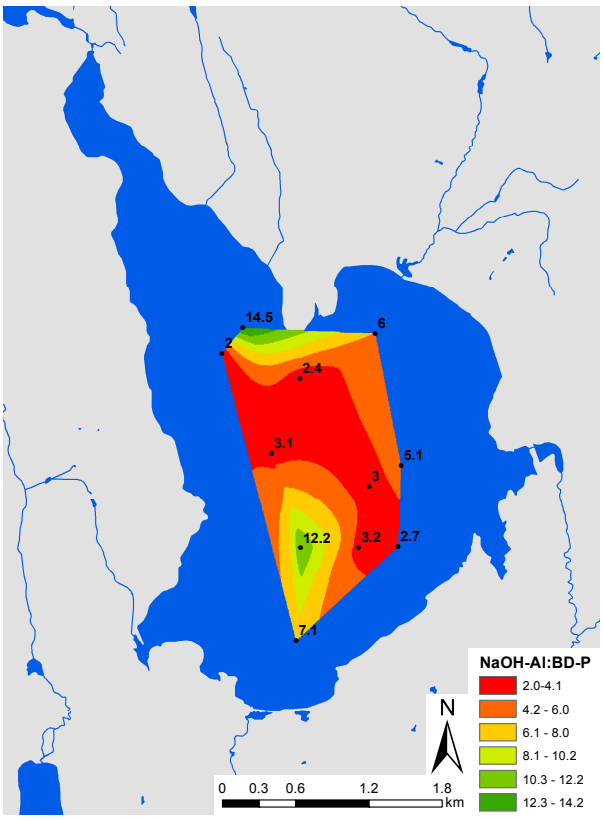
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Connecting climate and land use to Sebago Lake drainage network processes

Basic Information

Title:	Connecting climate and land use to Sebago Lake drainage network processes
Project Number:	2014ME305B
Start Date:	3/1/2014
End Date:	3/1/2015
Funding Source:	104B
Congressional District:	ME-2
Research Category:	Water Quality
Focus Category:	Geomorphological Processes, Sediments, Management and Planning
Descriptors:	None
Principal Investigators:	Sean Michael Smith

Publications

1. Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. Amtrak Club Meeting. Newark, Delaware, May, 2015.
2. Gerard, B., Smith, S., Sivitskis, A., Reave, A., and B. Van Dam. Human Modifications and Watershed Hydrologic Processes in a Postglacial Landscape. American Geophysical Union Joint Assembly. Montreal, Quebec, Canada, May, 2015.
3. Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. University of Maine Graduate Student Exposition. Orono, Maine, April, 2015.
4. Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. Maine Water and Sustainability Conference. Augusta, Maine, March, 2015.
5. Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. Geological Society of America Northeastern Section’s Annual Meeting. Bretton Woods, New Hampshire, March, 2015.
6. Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. Maine EPSCoR State Conference. Orono, Maine, December, 2014.

Status Report to: The Maine Water Resources Research Grants Program, FY 14

Submitted by: Dr. Sean M.C. Smith, School of Earth and Climate Sciences, Sen. George J. Mitchell Center, University of Maine, Orono, Maine

Date: May 27, 2015

Title: Connecting climate and land use to Sebago Lake drainage network processes

Project Number: 5406025

Focus categories: G&G, HYDROL, MOD, NPP, SED, SW, WQL, WQN, WS

Keywords: Channels, Climate, Geomorphology, Impoundments, Land Use, Streams, Urban Drainage, Watershed Management

Project Duration: March 2014 – Aug. 31, 2015 (extension to be requested to Dec. 31, 2015)

Funds: $34,004

Project Investigator: Dr. Sean M.C. Smith, School of Earth and Climate Sciences, Sen. George J. Mitchell Center, University of Maine, Orono, Maine

Students Supported Under the Award: Brett Gerard, School of Earth and Climate Sciences

Congressional District: Second

Problem Description

This project is focused on the effects of climate and land cover on the erosion and transport of materials in tributaries draining into Sebago Lake. The work leverages data and results from an ongoing hydrologic evaluation of the lake watershed, using information to estimate sediment flux and geomorphic adjustment in selected drainage network locations. Hydrologic simulation are being used to create runoff scenarios driven by specified land cover and climate conditions that conform to informed estimates of past, present and future conditions in the region. Since water flow characteristics in the tributaries govern erosion and transport of sediment, the hydrologic simulations provide a basis to examine patterns of tributary adjustment and sediment loading to the lake under tested scenarios. Our measurements and simulations are framed to provide guidance for watershed land use planning, nonpoint pollution management, aquatic habitat conservation, and protection of the drinking water sources in the region.

This project is focused primarily on the Sebago Lake system of southern Maine. The area is predominantly rural and forested despite a history of human interventions. This may change over the next thirty years as the region is expected to face land use and land cover (LULC) changes from growth and suburban development (U.S. EPA 2009). The demands on water resources and the uncertainty of runoff problems nonpoint source pollution from increased urbanization make the Sebago Lake system a high priority location for water resource research in New England. More information is necessary to identify and clarify the processes that influence outflow from tributaries, as well as the physical connections between the lake, contributing drainage systems, and upland landscapes.

The objectives of this ongoing project are as follows: 1) Identify dominant tributary settings in southern and coastal Maine, with a particular interest in the Sebago Lake watershed; 2) Quantify geomorphic and hydraulic conditions, and sediment entrainment and transport characteristics in selected tributary setting within the region; 3) Estimate changes to hydrology, channel conditions and sediment loads for selected tributary watersheds under varied scenarios of watershed land cover and climate. This report summarizes ongoing efforts to address these objectives.

Work Performed

Site Selection: During the summer of 2014, five sub-watersheds of Sebago Lake were selected for geomorphic reconnaissance. Study reaches span a range of watershed sizes to consider upland channels traversing hillslopes and lowland channels set in larger valleys. Our approach to site selection incorporated varied land use characteristics, soil conditions, geologic settings, and valley and channel morphologic characteristics. While the original project extent was confined to the Sebago Lake watershed, two coastal watersheds were added to our field data inventory. These additions were made to provide a more extensive basis to compare headwater (i.e., low order) streams outside of the marine transgression limit, the coastal proximal region where marine sediments were deposited over glacial till following the retreat of the Laurentide Ice sheet around 12 kya (Borns, et al., 2004), with inland headwater streams and higher order streams surveyed more extensively by the USGS for hydraulic geometry evaluations (Dudley, 2004). The coastal watersheds include the Webhannet River draining to Wells Harbor at the Wells National Estuarine Research Reserve and Cromwell Brook originating within Acadia National Park. In total, 37 stream reaches were examined (27 from Sebago, 8 from the Webhannet, and 2 from Cromwell) (Fig. 1).

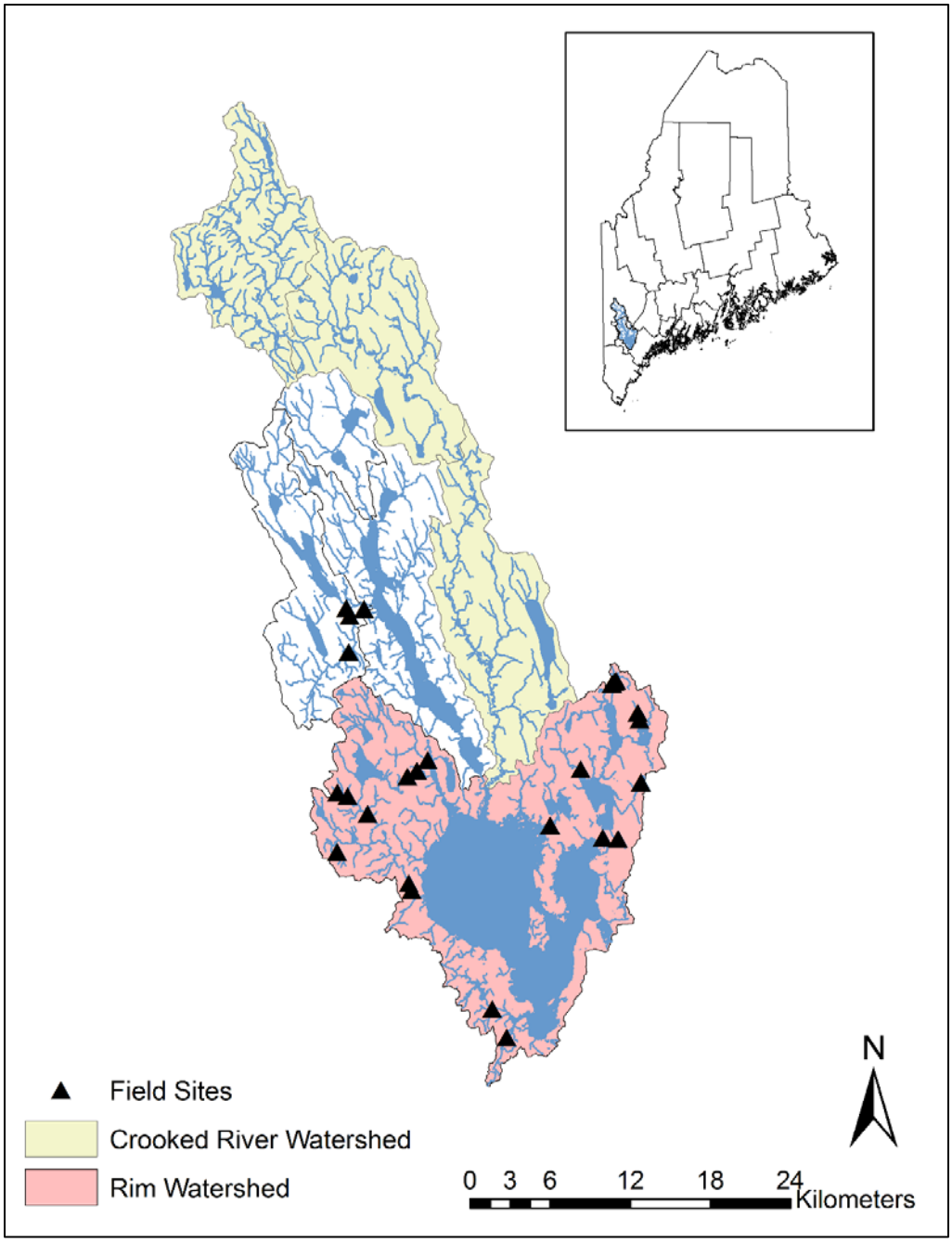

Figure 1. Study sites within the Sebago Lake watershed.

Geomorphic Reconnaissance: Our work has focused on five sub-watersheds draining to Sebago Lake, including Northwest River, Panther Run, Muddy River, and Stevens Brook. These watersheds range in size from 10 km^2 (Stevens Brook) to ~150 km^2. Relief of the watersheds is generally modest with an average elevation standard deviation of ~30 m. The surficial geology of the sub-watersheds is dominated by glacial till; however, there is a mix of wetland deposits in

the Northwest River, glacio-fluvial deposits in Stevens Brook, and glaciomarine deposits along the southern end of the lake watershed that is within the extent of marine transgression. Present development conditions are low to moderate with the exception of Stevens Brook which is ~22% developed.

Outside the Sebago Lake Region, the Webhannet River watershed covers 13 km^2 of mostly low relief terrain (elevation range of 71 m and a standard deviation of 9 m). The area is moderately developed (~11%) and has a long history of human interventions. The surficial geology of the Webhannet watershed is predominantly composed of marine clays and sands (Smith 1999a; Smith 1999b), relating to its location east of the line of marine transgression. The Cromwell Brook watershed is located on Mount Desert Island, ~70km southeast of Bangor, Maine. This watershed covers ~ 18km^2, has moderate to high relief (elevation range of 465 m and a standard deviation of 114 m), and thin or absent soils underlain by the Cadillac mountain granite. The watershed is moderately developed (19%), mostly concentrated in the lowland coastal region.

Geomorphic Characterizations: We completed topographic surveys in 37 stream reaches with a total station to evaluate the baseflow water surface slope and cross section dimensions for bankfull conditions (width and depth). Bankfull was identified using features such as the top of the bank, the backs of point bars, benches, changes in sediments, or changes in vegetation (Williams 1978). For all reaches within the Sebago Lake and Webhannet watersheds, bottom substrate conditions were measured using the Wolman pebble count methodology (Buffington and Montgomery 1999; Wolman 1954).

Hydrologic Signatures: Hydrologic evaluations conducted in this project have included field measurements of base flow discharges, continuous flow monitoring at tributary gage stations using stage-discharge rating curve methods, and real time monitoring using acoustic Doppler profiling approaches.

Baseflow discharge was measured at each study location using the mid-point method (Gupta et al. 1989) and an acoustic Doppler velocimeter. An acoustic Doppler profiler was deployed into the Songo River, a major lake tributary near our study locations, to contribute to the flow monitoring dataset collected from eight Sebago Lake tributary monitoring stations established by Reeve et al. (2013). The ADP measurements and other ongoing station operations are providing the data necessary to establish hydrologic fingerprints relevant to the stream reaches we have selected for evaluation. Data are hosted on a web server that can be accessed via the following link: https://stormcentral.waterlog.com/public/BlackBear2014.

We have concurrently refined the flow rating curve for the Northwest River monitoring station to provide more accurate discharge time series for our hydrologic and hydraulic characterizations (Fig. 2). A second ADP device is planned for deployment in the Northwest River in summer 2015 to provide real time discharge data and further refine the discharge estimates by measuring high flows beyond the extent of the existing rating curve.

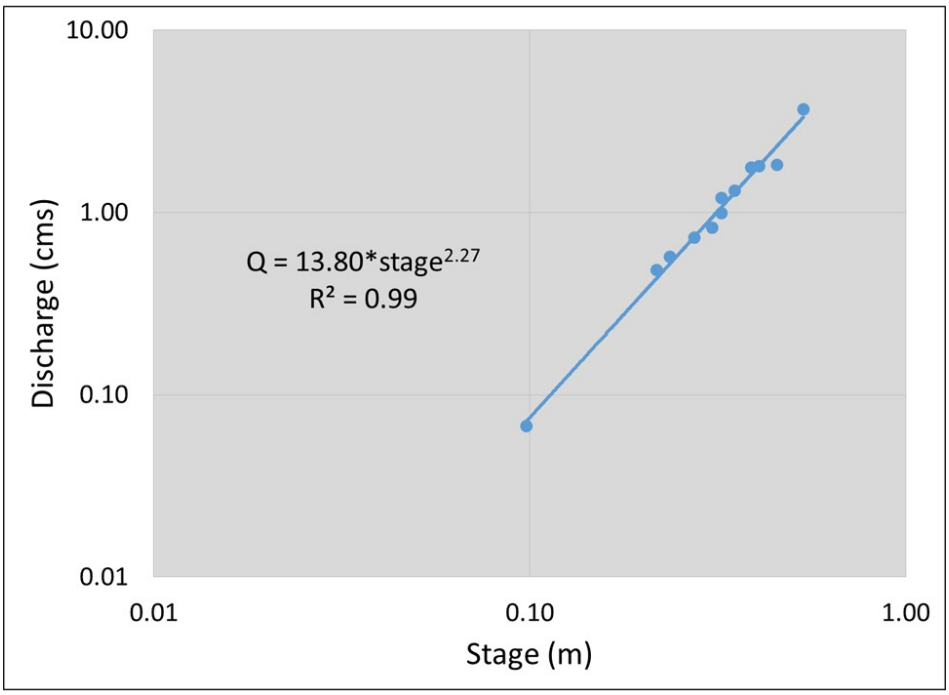

Figure 2: Northwest River discharge rating curve.

Baseflow hydrograph analysis was performed using the discharge time series from the Northwest River as part of the calibration process (Fig. 3). This analysis examined the subsurface storage properties of the system and their influence on baseflow recessions using methods described by Kirchner (2009).

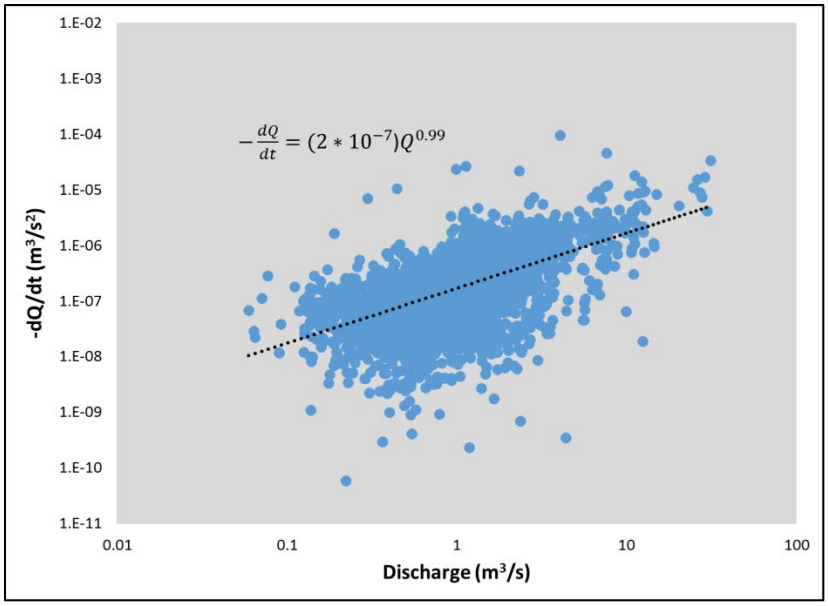

Figure 3. A recession plot defining the fit of a theoretical linear reservoir to the baseflow discharge in the Northwest River.

The flow monitoring data is being used to quantify storm hydrograph characteristics and to calibrate and validate a distributed watershed model for the Northwest River watershed using the MIKESHE modeling platform (DHI, 2012). We use the Nash-Sutcliffe Efficiency criteria (NSE) as a measure of model fit (Nash and Sutcliffe 1970) (Figure 4). A watershed model has also been parameterized for the Webhannet River watershed and will be further refined throughout the summer and fall 2015.

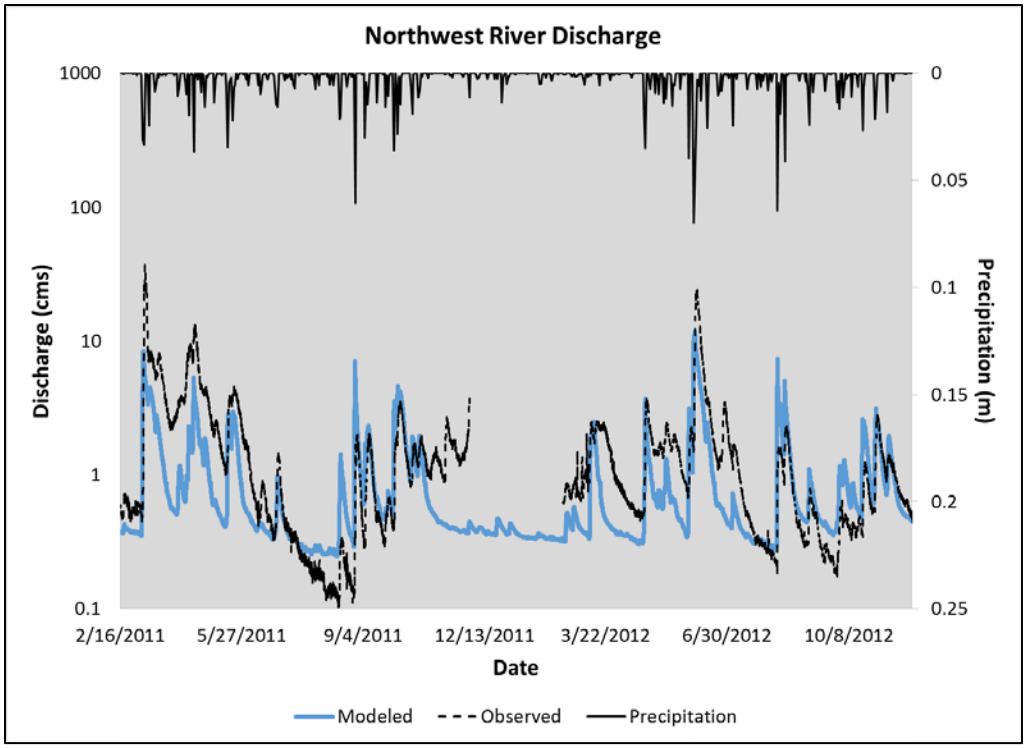

Figure 4. A plot of modeled (Blue) and observed (Black-Dashed) discharge at the outlet of the Northwest River. For the summer of 2011 (validation dataset) the NSE=0.69, and for the summer of 2012 (calibration dataset) the NSE=0.53.

Hydraulic Evaluations:

Topographic survey data collected from selected study reaches is being used to parameterize the watershed hydrologic model for the Northwest and Webhannet Rivers. Hydraulic roughness in our selected study reaches has been estimated using a steady uniform flow calculation approach. Survey and pebble count data are being used in conjunction with watershed hydrology simulation results to evaluate channel bottom sediment dynamics in selected study reaches using approaches described by Wilcock et al. (2009).

Downstream hydraulic geometry relations have been developed from our topographic survey and flow data using the approach described by Leopold and Maddock (1953). The relations are compared to results from regional curves for southern and coastal Maine developed by Dudley (2004) (Fig. 5). At-a-station hydraulic geometry curves are also being compiled for comparison to the results from stream reaches investigated by Dudley.

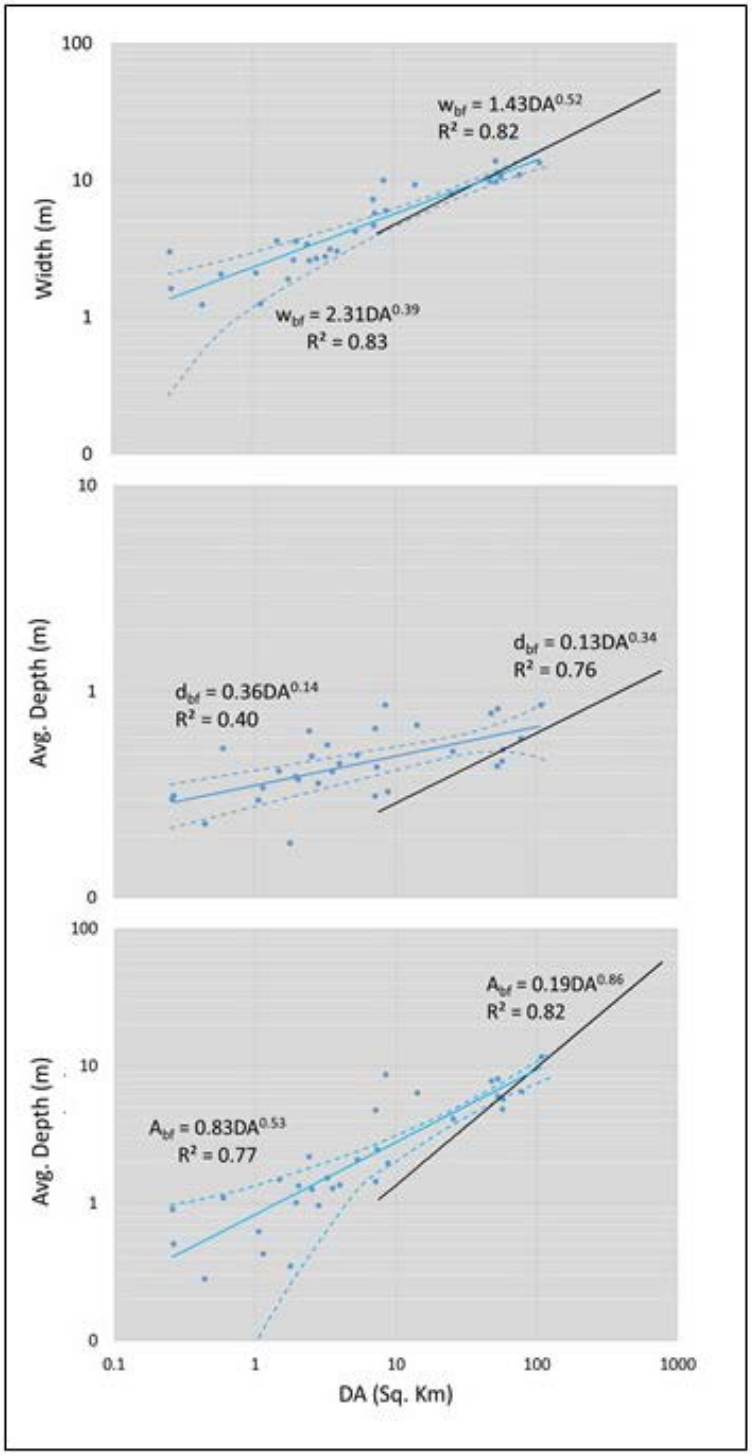

Figure 5. Downstream geometric relations for the measured locations within the Sebago Lake watershed (Blue) plotted against downstream hydraulic geometry curves developed by Dudley (2004) for southern and coastal Maine (Black).

Results

Hydraulic geometry relations developed from our survey data differ slightly from those developed by Dudley (2004). The results may reveal the relevance of local conditions on hydraulic geometry relations as suggested by previous work (Bieger et al. 2015). The relations we have produced quantify much smaller drainage areas than previous Maine datasets developed by Dudley (2004). While defining this relation in upland river systems presents complications related to the alluvial or non-alluvial nature of these systems, there is some coherence in our data and we believe the results characterize the dimensions of relatively small headwater channels in central and coastal Maine.

The distributed model that we have parameterized for the Northwest River watershed simulates discharge at the outlet of the river reasonably well with a performance efficiency of 0.53 for calibration dataset and 0.69 for validation dataset (optimal performance efficiency = 1). The model is currently calibrated for summer months; however, we have completed tasks related to snow melt simulations. Scenarios related to a range of human modifications to the landscape and channel network have been developed and preliminary results point to the importance of the subsurface flow component in the region.

Baseflow hydrologic analysis indicates a steep baseflow recessions in the Northwest River. This suggests a small subsurface storage component in the system, which is reasonable considering the shallow overburden thickness and the well-drained nature of the soils. Calculations from the linear reservoir theory evaluation presented by Kirchner (2009) indicate an average storage depth in the subsurface of ~6 m, which matches well with overburden thickness measured from wells in the Northwest River watershed. This result and the challenges of simulating low discharge periods in the distributed model for the Northwest River may indicate the importance of surface storage in the system, a component that may also be important when considering the hydrologic effects of LULC change.

Our research activity will be continued in summer 2015. Watershed models will be refined in the Northwest River, calibrated in the Webhannet River, and parameterized in the Cromwell Brook watershed. Results will be used to evaluate changes in hydrologic signatures linked to channel bottom stability (i.e., incipient sediment motion). More study reaches will be evaluated to better represent the statistical relevance of the hydraulic geometry relations observed in our study areas. Further work will be completed on factors influencing varied hydrologic conditions, channel dimensions and sediment transport characteristics in our selected study areas.

Published abstracts resulting from the award:

Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. *Amtrak Club Meeting.* Newark, Delaware, May, 2015.

Gerard, B., Smith, S., Sivitskis, A., Reave, A., and B. Van Dam. Human Modifications and Watershed Hydrologic Processes in a Postglacial Landscape. *American Geophysical Union Joint Assembly.* Montreal, Quebec, Canada, May, 2015.

Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. *University of Maine Graduate Student Exposition.* Orono, Maine, April, 2015.

Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. *Maine Water and Sustainability Conference.* Augusta, Maine, March, 2015.

Gerard, B., Smith, S., Van Dam, B., and A. Reave. Stream Dynamics in a Coupled Human-Climate-Postglacial Watershed. *Geological Society of America Northeastern Section's Annual Meeting.* Bretton Woods, New Hampshire, March, 2015.

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Information Transfer Program Introduction

Information Transfer activities for the Maine Water Resources Research Institute (MWRRI) are an important part of our mission. Information Transfer activities can be categorized as: (1) Conferences- Hosting the Maine Water and Sustainability Conference; (2) Producing web-based water information; (3) Participation on state-wide boards and committees; (4) Leading educational outreach such as K-12 STEM projects (GET WET!); (5) Publishing newsletters (electronic versions); and (6) Providing direct responses to inquiries from citizens. In additional to the effort made directly by the MWRRI, we require researchers funded through the 104b program to include information transfer in their projects. Required information transfer activities include presenting research results at the Maine Water and Sustainability Conference, production of a one-page project fact sheet written for a general audience, a progress report, and a manuscript for publication. We also encourage researchers to link research outputs to direct stakeholder interactions and K-12 curricula.

The Maine Water and Sustainability Conference is the leading event in the state and brings together a very broad array of water-interest groups. This conference is very popular and continues to be the most important information transfer event for the MWRRI. Our web page is the location to find information for current issues, activities, and publications. The web page is co-located with the Mitchell Center's and is updated on a regular basis to include project outputs such as publications and presentations. Also, it serves as a notice board for meetings, student opportunities, and calls-for-proposals. Periodic messages are also web-broadcasted to alert our community to important news, events, and opportunities.

The Water Institute Director serves on several state-wide and national boards and committees (e.g. Maine Water Utilities Association, New England Interstate Water Pollution Control Commission, Penobscot River and Bay Institute, American Water Works Association, National Institutes for Water Research). These activities provide opportunities to promote relevant institute-sponsored research and education. Also, it provides a process for the MWRRI to collect information about the concerns and challenges of water resources in the state and region. This effort helps to keep the MWRRI at the core of water resources in the state and region.

Finally, the MWRRI receives public inquiries on a regular basis. Typically, someone is hoping that outcomes from funded projects can help solve their water-related problem or that new research is focused on a topic important to them. Responding to these inquiries is a priority and we make every effort to help citizens in finding answers and solutions to their problems. Although most inquiries come from Maine, we have received requests from around the globe.

Maine Information Transfer

Basic Information

Title:	Maine Information Transfer
Project Number:	2014ME304B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	1
Research Category:	Not Applicable
Focus Category:	Education, Law, Institutions, and Policy, None
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publications

There are no publications.

Publications

Peer Reviewed Publications

Ahern, John C**.,** R. Fairchild, T. Jin-Sun, J. Carr, H. Patterson, 2015. "*Photocatalysis of Pharmaceuticals Over BiOX Catalysts (where X= Cl or I).*"*Applied Catalysis B: Environmental*. (Accepted)

Beyene, M.T., Jain, S. (2014). Winter weather-climate variability and its links to early ice breakup dates in Maine lakes. *Journal of Climate*.

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Bell, K.P., B. Vanderlugt, A. Kaminski, J. Balukas**.** 2015. *Assessing Spatial Heterogeneity in Behaviors and Attitudes: Implications for Land and Water Resource Management in a Changing Environment.* 2015 W-3133 USDA NIFA Multistate Project Meeting, Pensacola, FL.

Beyene, M.T., Jain, S. (2014). *Abstract - Winter weather-climate variability and its impact on early ice break up dates in Maine lak es*. 28th Conference on Hydrology.

Brown, R.E., Saros, J.E., Nelson, S.J. 2014. *Algal community response to increases in dissolved organic carbon over recent decades.* 22nd Annual Harold W. Borns Symposium. University of Maine, Maine.

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Kaczor, Keri, B. Bell, J. Bird. 2014. *Clean Water: Working Together To Find Solutions.* Presentation, Maine Sustainability & Water Conference, Augusta, ME.

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Levesque, Vanessa, K. Bell, A. Calhoun, M. Teisl. 2014. *A Collaborative Economic And Ecological Analysis Of A Proposed Vernal Pool Regulatory Mechanism*. Presentation, Maine Sustainability & Water Conference, Augusta, ME.

McGreavey, B. 2014. *Moving across disciplines, Institutions, and Scales: A Frenchman Bay Case Study*. Maine EPSCoR Conference, University of Maine, Orono, ME.

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Thornton, T., J. Peckenham. 2014. *Incorporating and Assessing Newly Implemented Common Core Objectives Through the Evaluation of a School-Centered, Community-Based Research (CBEMR) Project Focused on Student Managed Groundwater Protection***.** 50th Annual American Water Resources Conference, Tysons Corner, VA.

Poster Presentations

Ahern, J., M.Theriault, N. Caputo, J. Killarney**,** H.Patterson. 2014. *Rapid Detection of Hormone and Petrochemical Contaminants in Natural Water Systems*. Poster, Maine Sustainability & Water Conference, Augusta, ME

Arvisais, Kyle**,** S.J. Nelson, S. Fraver. 2014. *Evaluating Spatial and Temporal Trends in Snowpack Across Maine*. Poster, Maine Sustainability & Water Conference, Augusta, ME

Brown, R.E., Saros, J.E., Nelson, S.J. 2014. *Algal community response to increases in dissolved organic carbon over recent decades*. Joint Aquatic Sciences Meeting. Portland, Oregon.

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Budzinski, Colleen **,** J. Jansujwicz, T. Johnson, G. Zydlewski, T. Koboski, J. Vieser, C. Bartlett. 2014. *Maine Tidal Power Initiative: Linking Knowledge to Action for the Responsible Development of Tidal Power in Maine*. Poster, Maine Water and Sustainability Conference. Augusta, ME.

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MacLagan, Stephanie**,** K.P. Bell, L. Silka, T. Johnson., J. East. 2014. *Analyzing the Economics of Shellfish Management Policy Structures*. Poster, Maine Water and Sustainability Conference. Augusta, ME.

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Maxwell, E., C. Paquette, T.R. Johnson . 2014. *From the Flat: Perceptions of Threats Facing Maine's Shellfish Industry.* Maine EPSCoR Conference, University of Maine, Orono, ME.

McGreavy, B., B. Suldovsky. 2015. *A Communication Systems Framework for Sustainability Science.* American Association for the Advancement of Science, San Jose, CA.

Neville, M. and K. Beard. 2014. *Old Data and New Technologies- Integrating legacy research for modeling future outcomes*. Maine Water and Sustainability Conference. Augusta, ME

Obomsawin,T., C.L. Noblet, K.P. Bell, M. Snell, A. Kaminsky. 2014. *Do Maine and New Hampshire Residents Prefer Shellfish Harvested Locally? Measuring the Supply and Demand of Shellfish Harvested in Maine and New Hampshire.* Maine EPSCoR Conference, University of Maine, Orono, ME.

Obomsawin, T., C. Noblet, K.P. Bell, A. Kaminsky, M. Snell. 2014. *How are Coastal Maine Residents Getting Information about Water Quality : Identifying Avenues for Communication About Water Quality Issues Using Surveys Administered to Coastal Residents***.** Maine EPSCoR Conference, University of Maine, Orono, ME.

Peckenham, J.M. and S. Peckenham. 2014. *Assessment of Quality for Middle Level and High School Student-Generated Water Quality Data.* Poster, Maine Sustainability & Water Conference, Augusta, ME.

Reeve, Andrew, S.Smith, D. Martin. 2014. *Coupling Streamflow, Simulated with Plumped Parameter Models, To a Lake Water-Balance Model (Sebago Lake, Maine)*. Poster, Maine Sustainability & Water Conference, Augusta, ME

Rudnicky, B**.,** J.M. Reynolds, K.M. Smith, J.A.Sulikowski. 2014. *Abiotic Influences on the Juvenile Fish Assemblage of the Saco River Estuary, Maine*. Poster, Maine Sustainability & Water Conference, Augusta, ME.

Sheldon, Patrick, J. Killarney, H. Patterson. 2014. *Kinetics of PPCP Absorption to Dissolved Organic Matter Using Flourescent Detection Methods*. Poster, Maine Sustainability & Water Conference, Augusta, ME.

Smith, Sean, B. Gerard, B. VanDam, A. Reeve. 2014. *The Hydrologic Implications of Human Interventions in a Post-Glacial Landscape*. Poster, Maine Sustainability & Water Conference, Augusta, ME.

Suldovsky, Brianne, S. MacLagan, B. McGreavy**,** K. P. Bell, S. Jones, L. Lindenfeld. 2014. *Decision-making Processes for Beach and Shellfish Management: A Scoping Analysis for NEST's Safe Beaches and Shellfish Project*. Poster, Maine Sustainability & Water Conference, Augusta, ME.

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Warner,K., K. Strock, M. Teisl, J. Saros. 2014. *Ecological and Economic Vulnerability of Maine Drinking Water Resources to Increased Frequency of Extreme Storm Events***.** Association for the Sciences of Limnology and Oceanography Conference, Portland, OR.

Ziwen, Y., I. Bricknell, R. Rawson, M. Wells, T. Johnson, S. Hanes. 2014. *Establishing the Relationship between Water Temperature and Depuration Rate of Eastern Oyster in Maine.* Maine EPSCoR Conference, University of Maine, Orono, ME.

Other Publications

News and Events
The Mitchell Center communications regularly via our "News & Events" publication with our email subscription list of 1,600 contacts using MailChimp. Mailings to the list occur every 2-3 weeks and include news articles, upcoming event information, and other items of interest to our stakeholders and subscribers. All articles link to the Mitchell Center website for more in-depth information.

A science writer assists the Mitchell Center with various materials that are written for distribution to public audiences. Materials include news stories, media releases and research project summaries. This allows us to keep content for our website, News & Events email, and Facebook page fresh and interesting. We also created a Faculty Experts Guide for our website and we continue to provide updates to online faculty and graduate student profiles. The Faculty Experts Guide is an important addition to our website and provides a one-stop-shop for media and stakeholders who are interested in connecting with sustainability science research expertise.

Conferences and Annual Events

Maine Sustainability & Water Conference 2014
The 2014 Maine Sustainability & Water Conference took place on April 1, 2014 at the Augusta Civic Center in Augusta, Maine. The conference included sessions on water resources research in Maine as well as several sessions on sustainability science research and sessions with a joint focus on water resources and sustainability. Plenary speakers were Robert Kates, Presidential Professor of Sustainability Science, University of Maine, (*Sustainability Science: Moving Knowledge into Action)* and Mark Borsuk, Associate Professor, Thayer School of Engineering at Dartmouth **(***Gambling with the Globe: The Role of Risk in Decision-Making for Sustainability).*

The Maine Water Conference was launched in 1994 by the Senator George J. Mitchell Center at the University of Maine to address one of Maine's central challenges– the future of its water resources. The conference was designed to provide a collaborative nexus for water resource professionals, researchers, consultants, citizens, students, regulators, and planners to exchange information and present new findings on water resource issues in Maine.

In response to many requests, we have expanded the conference's focus to encompass a wider range of challenges facing Maine. We did so for several reasons:

- Water is a central issue for Maine's well-being, but it is often intertwined with many other issues, including the well-being of our forests, farms, coastal systems, towns and cities.

- Understanding and solving water resource problems will require an increased focus on interactions between the well-being of ecosystems and Maine's people.
- Efforts to address these connected environmental, social, and economic challenges will benefit from greater participation by a wide range of stakeholders, including the public and private sectors, non-governmental organizations, academic institutions, and citizens.

Sponsorship for the 2014 Maine Sustainability & Water Conference was provided by: U.S. Geological Survey, Senator George J. Mitchell Center and the Maine Water Resources Research Institute, National Science Foundation, Maine EPSCoR, Maine Geological Survey, Maine Water Utilities Association, Maine Volunteer Lake Monitoring Program, Portland Water District, Maine Water, Maine Lakes Society, and the University of New Hampshire.

Senator George J. Mitchell Lecture on Sustainability

William Clark, of Harvard University's John F. Kennedy School of Government, delivered the 2014 Senator George J. Mitchell Lecture on Sustainability on October 2, 2014 at the University of Maine. His talk was titled, "*Mobilizing Knowledge to Shape a Sustainable Future*." Almost 500 people attended the lecture of which ~25% were external constituents and stakeholders. Senator George Mitchell provided comments following the keynote address. Videos of all past Mitchell Lectures are available on the Mitchell Center website at http://umaine.edu/mitchellcenter/mitchell-lecture/.

2014 Northern Maine Children's Water Festival

The Mitchell Center is a proud sponsor of the Northern Maine Children's Water Festival which promotes hands on learning about water issues. This one-day event, held on October 14, 2014 at the University of Maine, brought together over 600 students and their teachers to explore water resource issues. Water resource professionals from Maine and New England provided presentations and activities about water, wetlands, human health and aquatic life; there were water trivia quiz shows hosted by local radio and television personalities, as well as activities involving music and art. This experience is provided at no cost to the participants. In fact, the festival provides funding to help schools pay the cost of transportation. The festival goals are to teach students about the value of clean water and healthy habitats, and to provide teachers with materials and lessons that they can use for years to come. Also, many activities are aligned with Maine's Learning Results. Schools are chosen to attend on the basis of their applications, what they currently teach about water, and how they will use the festival experience in their curriculum. The Mitchell Center works with the Maine Department of Environmental Protection and several other sponsors to bring the festival to the University of Maine every other year.

Media/Press

Press Releases

- Maine Sustainability & Water Conference Spotlights Urgent Local, Regional and Global Issues
  March 26, 2014
- Almost 700 children expected to attend the Northern Maine Children's Water Festival
  October 10, 2014

- Frogs, Floods and the Future: Balancing Environment & Economy on Mount Desert Island
  July 14, 2014

In the Media

- "This is a huge success story": 2 Maine scientists say acid rain effects reversing much faster than expected
  Bangor Daily News – August 15, 2014
- What drives general acceptance of offshore wind farms?
  European Commission – Science for Env. Policy, July 10, 2014
- Op-Ed – Bay to Baxter: As the Penobscot River changes, so must we
  Bangor Daily News, July 11, 2014
- UMaine researchers helping coastal communities weather the storms
  Bangor Daily News, June 26, 2014
- Op Ed: Keeping up with Maine's Changing Climate
  Bangor Daily News, June 25, 2014
- Wabanaki baset makers' livelihood, invasive beetle interwoven
  Portland Press Herald, April 22, 2014
- UMaine grad student researching effects of weather, climate change on maple sugaring industry
  Huffington Post, April 2, 2014
- Sewage sniffing dog, sustainability featured at Augusta conference
  Kennebec Journal, April 2, 2014
- Augusta conference to focus on water and sustainability issues
  Morning Sentinel, April 1, 2014
- Augusta Conference to focus on water and sustainability issues
  Kennebec Journal, April 1, 2014

Web/Newsletter Stories

- High School Students Brave Cold, Snow to Gather Snowpack Data
  http://umaine.edu/mitchellcenter/news/news-2/high-school-students-brave-cold-snow-to-gather-important-snowpack-data/
- Student Research Spotlight: Looking for Warning Signs Beneath the Surface
  http://umaine.edu/mitchellcenter/news/news-2/student-research-spotlight-looking-for-warning-signs-beneath-the-surface/
- Are Some Shellfish Beds and Beaches Closed Needlessly?
  http://umaine.edu/mitchellcenter/news/news-2/are-some-shellfish-beds-and-beaches-closed-needlessly-mitchell-scientists-take-a-closer-look/
- Upland Suburban, Agricultural Areas Contribute "Lion's Share" of Sediment Load
  http://umaine.edu/mitchellcenter/2015/01/29/upland-suburban-agricultural-areas-contribute-lions-share-of-sediment-load-today/

- Citizen Science Project Examines Mercury Contamination in Dragonfly Larvae http://umaine.edu/mitchellcenter/2015/01/05/citizen-science-project-examines-mercury-contamination-in-dragonfly-larvae/
- Researchers, Lobstermen Seek Solutions to Fish's Decline as a Team http://umaine.edu/mitchellcenter/2014/12/09/researchers-lobstermen-work-as-team-to-salvage-potentially-endangered-fish/
- Students Learn Lessons in Sustainability at Water Festival http://umaine.edu/mitchellcenter/2014/10/27/students-learn-lessons-in-sustainability-at-water-festival/
- Communities Invested in River Restoration http://umaine.edu/mitchellcenter/news/news-2/communities-invested-in-river-restoration/
- Researchers Investigate Impact of Aging Infrastructure, Human Activities on Coastal Waters http://umaine.edu/mitchellcenter/news/news-2/researchers-investigate-impact-of-aging-infrastructure-human-activities-on-coastal-waters/
- Colby Team Builds Sustainability Coalition in Belgrade Lakes Region http://umaine.edu/mitchellcenter/news/news-2/colby-team-builds-sustainability-coalition-in-belgrade-lakes-region/
- Mitchell Center Researcher Sarah Nelson in BDN – Good News for Maine Lakes http://umaine.edu/mitchellcenter/2014/08/20/mitchell-center-researcher-sarah-nelson-in-bdn-good-news-for-maine-lakes/
- Maine Reap Benefits of 50-yr-old Water Resources Research Act http://umaine.edu/mitchellcenter/news/news-2/maine-reaps-benefits-of-50-year-old-water-resources-research-act/
- Sustainability Science in Action: Can Citizens Help Manage Herring Fisheries? http://umaine.edu/mitchellcenter/news/news-2/sustainable-science-in-action-can-citizens-help-manage-herring-fisheries/
- Vernal Pools Conservation Calls for Diverse Perspectives http://umaine.edu/mitchellcenter/2014/07/14/scholarly-article-vernal-pools-conservation-calls-for-diverse-perspectives/
- Improved Fish Advisory for Pregnant Women http://umaine.edu/mitchellcenter/news/news-2/improved-fish-advisory-for-pregnant-women/
- Accelerated Recovery of Maine Lakes http://umaine.edu/mitchellcenter/2014/06/02/accelerated-recovery-of-maine-lakes/

Committees and Service

David Hart

- Member, Science and Technical Advisory Committee, American Rivers
- Member, Sustainable Oceans, Coasts, and Waterways Advisory Committee, Heinz Center for
  Science, Economics, and the Environment, 2004 – present.

- Member, President's Advisory Committee on Water Information (representing the Ecological Society of America), 2003 – present.

John Peckenham

- Board Member (New England Regional Representative), National Institutes for Water Research.
- New England Private Well Initiative – Water Quality Extension and US EPA Region 1
- Source Water Collaborative and American Water Works Association Source Protection Committee
- New Business Development – Maine Water Security LLC (managing partner), Mainely Sensors
  LLC (consultant), Zeomatrix (consultant)
- Penobscot River Keepers
- Groundwater Education Through Water Evaluation and Testing, GET WET!
- River Flow Advisory Commission- Drought Task Force
- Maine Water Conference Organizing Committee
- Maine Water Utilities Association- Water Resources Committee
- Sustainable Water Withdrawal- Land and Water Resources Council
- Maine Waste Water Control Association- Residuals Management Committee
- Penobscot River and Bay Institute- Board of Directors
- Northern Maine Children's Water Festival
- Department of Environmental Protection-Consulting Engineers of Maine Task Force
- New England Water Quality Extension Advisory Board

Sarah Nelson

- Lead scientist, Collaborative Scientific Research program, Old Town High School 2012-2014.
- Lead scientist, Developing indicators for comparative watershed mercury burdens: dragonfly larvae pilot study and citizen science initiative, in cooperation with Colleen Flanagan, NPS-Air Resources Division, Denver, CO, 2011-2012. Thirteen parks across the US are participating.
- John Wesley Powell Center Working Group on mercury cycling, bioaccumulation, and risk across North America, participant and invited to author manuscript. 2013-present.
- Steering Committee member, Northeastern Ecosystem Research Cooperative (NERC), 2013 – 2017 term.
- Convener, Mercury in Acadia and northeast protected areas. In collaboration with NPS-ARD, NPS-Acadia, SERC Instititute
- Lead scientist, Acadia Learning project, 2007-present
- Steering committee member, Acadian Internship in Regional Conservation and Stewardship, 2010-present
- Steering committee member, Downeast and Acadian Inititative, 2010-present
- Maine Water Conference, Science Program Chair, 2010-present
- Acadia Web Portals working group, coordinator, 2009-2010
- Scientist-teacher liaison, Acadia Learning project, 2007-present
- MDI Water Quality Coalition student mentor, 2006-present

- Appalachian Trail Environmental Monitoring Program, Water Quality Working Group
- Coordinator, University of Maine Mercury Research Group, 2006-present
- Maine Water Conference Organizing Committee

Brian McGill

- Editorial Board, Frontiers in Ecology & Environment
- Conference Section Chair, GRC Conference on Unifying Ecology Across Scales
- Blogger - One of 3 co-bloggers on leading blog in academic ecology.

Sean Smith

- Advisory Board, Maine Lakes Environmental Association
- Conference Section Chair, Session on Ecohydrology and Sustainability, Geol. Soc. of America - NE Section Meeting

Tim Waring

- Conference Section Chair, Society for Human Ecology XXth conference, Bar Harbor, Evolutionary Conservation Session
- Conference Section Chair, International Association for the Study of the Commons, University of Alberta, Edmonton, Canada. Cultural Evolution and the Commons: Empirical Applications of a Multi- Level Evolutionary Framework Session
- Grant Review Board Member, National Science Foundation, Science of Organizations
- Peer Review, Evolution and Human Behavior
- Peer Review, Journal of Bioeconomics
- Peer Review, Frontiers in Ecology and the Environment

Other Activities

Senator George J. Mitchell Center for Sustainability Solutions

In July 2009, the Senator George J. Mitchell Center was awarded a $20 million, five-year grant by NSF EPSCoR to support Maine's Sustainability Solutions Initiative. As the initial grant ended December 31, 2014, the creation of the Mitchell Center for Sustainability Solutions ensured that the synergy between SSI and the Maine WRRI program continues to provide important leveraging opportunities for water resource projects across the state. A key component of the SSI project was its partnership with 12 other educational institutions across Maine. All of these institutions were funded to conduct research under the SSI program – many related to water resources in Maine. WRRI Co-Director John Peckenham acts as liaison between the Mitchell Center and the partner institutions, continuing relationships that also strengthen the WRRI program. It is also important to note that many faculty who have been funded under the WRRI research program were key collaborators on the SSI project and remain active members of the Mitchell Center's research program.

Partner institutions include: Bates, Bowdoin, Colby, Unity, University of New England, University of Southern Maine, University of Maine at Farmington, University of Maine at Augusta, University of Maine at Presque Isle, University of Maine at Fort Kent.

New England Sustainability Consortium (NEST)
In fall 2012, UMaine and UNH collaborated on a joint proposal for NSF EPSCoR's RII Track 2 solicitation. The project titled, "*Collaborative Research: Strengthening the scientific basis for decision-making: Advancing sustainability science and knowledge-action capacities in coupled coastal systems*" was approved for funding and started August 1, 2013. The **N**ew **E**ngland **S**us**T**ainability Consortium (NEST) is a regional research partnership focused on strengthening the scientific basis for decision-making regarding the management of coupled coastal systems. NEST is mobilizing cutting-edge theory and methods from the emerging field of sustainability science and a range of disciplines to tackle problems related to the closure of shellfish beds and posting of beach advisories due to high levels of pathogenic bacteria in coastal regions. Many of the faculty participating on this project are members of the Mitchell Center, including three faculty directly supported by the Mitchell Center (Ranco, Smith and McGill).

Mitchell Center Seminars

- February 23, 2015
  John M. Hagan, Manomet Ctr. for Conservation Sciences
  The Science of When Science Doesn't Matter (and What to Do About It)
- Monday February 9, 2015
  Cindy Isenhour, Dept. of Anthropology, UMaine
  Materials Management through Sustainable Consumption: Research, Policy and Practice
- Monday, September 15, 2014
  Damian Brady, School of Marine Sciences, University of Maine
  How Models Influence Environmental Policy Decision-Making: Lessons Learned from Models of Nutrient Loading and Hypoxia
- Friday, September 19, 2014
  Bobbi Peckarsky, University of Wisconsin-Madison
  Potential effects of climate change on stream organisms
- Monday, September 22, 2014
  Rebecca Jordan, Rutgers University
  Development of Citizen Science Programs and Evaluation of Outcomes
- Friday, September 26, 2014
  Dan Murphy, University of Cincinnati
  Engaging Future Vulnerability and Adaptation Using Landscape-scale Iterative Scenario-Building
- Monday, October 6, 2014
  Nicholas Giudice, School of Computing and Information Science, University of Maine
  Using virtual reality as a tool for improving wind energy visualization

- Monday, October 20, 2014
  Dave Owen, University of Maine School of Law
  Trading Dams: The Penobscot River Restoration Project and the Future of Dam Law

- Monday, October 27, 2014
  Jon Devine, Senior Attorney, Water Program, Natural Resources Defense Council
  We All Swim Downstream: Policy Solutions to Beach Water Pollution

- Monday, November 3, 2014
  Jonathan Kramer, National Socio-environmental Synthesis Center
  Building Capacity for Socio-Environmental Problem Solving: A Design for Learning and Adaptation at SESYNC

- Monday, November 10
  Robin Alden, Executive Director, Penobscot East Resource Center
  Ecosystem management in a changing climate: What do fishermen have to do with it?

- Thursday, November 13
  Peter Wilcock, Johns Hopkins University; Utah State
  Sediment, scale, and stakeholders – clearing the muddy waters of the Minnesota River Watershed

- Monday, November 17
  Yong Chen and Christine Beitl
  School of Marine Sciences, Dept. of Anthropology, University of Maine
  Collaborative Interdisciplinary Research for Understanding Bycatch in the Maine Lobster Fishery

Web Site
The Mitchell Center website has been reorganized and is available at www.umaine.edu/mitchellcenter. News updates and event information are prioritized on the home page which keeps the site fresh and informative.

Facebook Page
The Mitchell Center has created a new Facebook page to post event updates, recent news stories, faculty and student accomplishments, and to share other posts from our partners that relate to sustainability science and water resources. The page is available at https://www.facebook.com/MitchellCenterForSustainabilitySolutions.

Video on Demand
Videos of Mitchell Center seminars, lectures and events are available for viewing on Vimeo. A list of available videos is provided on the website at:
http://umaine.edu/mitchellcenter/home/news/multimedia/video-on-demand/

Impact on Technology Transfer

The Mitchell Center's impact on technology transfer is being achieved in two ways: 1) through the transfer of results to entities in government, tribal communities, the private sector, and non-governmental organizations; and 2) via the adoption of new practices by those organizations. Specific examples of the Mitchell Center's roles in technology transfer include:

- Collaboration with the Wildlife Conservation Society and Colorado State University on a conservation planning manual
- Collaboration with a national research team on vernal pool national policy and future research initiatives
- Engaged communities in York and Cumberland counties in a full regional scale planning effort for sustainable development
- Maine Futures Community Mapper (MFCM) utilized by Androscoggin Valley Council of Governments (AVCOG) in town planning processes. The MFCM provides a linkage between Mitchell Center research and various stakeholders, and is considered a model "best practice" for sustainability science.
- Collaboration with the Highland Lake Association to start a volunteer alewife count at Highland Lake in the Presumpscot River drainage as the first step towards a harvest independent assessment of alewife passage at a non-harvested site.
- Work in collaboration with the Belgrade Regional Conservation Alliance, Belgrade Lakes Association, and Maine Lakes Resource Center to develop a Belgrade Lakes Watershed plan.
- Created the Saco River Estuary Stewardship Network. Provided stakeholders with information about threats to the estuary, including sea level rise, invasive Phragmites australis, water pollutants (nutrients and E. coli), and land use change in the shoreland zone. Working with stakeholders to manage these threats.
- Worked on pond level management strategy in attempt to improve water quality of Quimby Pond.
- Provided collaborative assistance to other pond interest groups about water quality monitoring and shoreline improvements.
- Developed three applications on Google Play and Apple App Store. Made continuous improvements in response to user reports and other needs.

Developments of user-friendly Decision Support System tools have the possibility of commercialization.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	14	18
Masters	2	0	0	20	22
Ph.D.	2	0	0	27	29
Post-Doc.	0	0	0	4	4
Total	8	0	0	65	73

Notable Awards and Achievements

Researchers Develop a Management Plan for Vernal Pools

Researchers have developed a Special Area Management Plan (SAMP) for vernal pools with the US Army Corps of Engineers. The plan includes a local in-lieu fee mechanism similar to a transfer of development rights. The research team has submitted a draft of the SAMP to the US Army Corps of Engineers for consideration for an alternative federal regulation of vernal pools in municipalities in Region 1. This document is currently under revision.

Award-Winning Spatial Mapping Tool Goes Live

Development of the Maine Futures Community Mapper was completed and the tool went live (http://www.mainelandusefutures.org/) in spring 2014. The MFCM was designed as an interactive spatial mapping tool that allows external stakeholders to apply the team's suitability models to planning issues of local and regional significance. The team continues to host workshops and give presentations demonstrating the model, its capabilities, and applications. It is anticipated that this will help broaden the use of the tool by local organizations. The Androscoggin Valley Council of Governments (AVCOG) used the MFCM in updating the Town of Hebron's comprehensive planning process. Presentations to local stakeholders include: AVCOG; PenBay Regional Land Trust; Orono Land Trust; Eastern Maine Development Corp; Maine Land Trust Alliance Annual Meeting; Regional Conservation Partnership Network Gathering.

Paper Focuses on Lessons Learned

The Mitchell Center's sustainability project demonstrated how research universities can more effectively draw upon and integrate their expertise in science, technology, engineering, and mathematics to help solve urgent sustainability societal challenges. Based on a multiple case study* of our project and five other projects at other major U.S. research universities, we have identified five lessons that can help researchers and research universities increase their problem-solving capacity:

- Lesson 1: Higher education must focus on solutions as well as knowledge
- Lesson 2: Solving sustainability problems requires interdisciplinary collaboration
- Lesson 3: Partnerships with stakeholders are essential
- Lesson 4: Innovative, creative organizations facilitate solutions
- Lesson 5: Research on organizational change helps create effective structure and culture

*Hart, David D., James L. Buizer, Jonathan A. Foley, Lewis E. Gilbert, Lisa J. Graumlich, Anne R. Kapuscinski, Jonathan G. Kramer, Margaret A. Palmer, David R. Peart, Linda Silka. 2014. Mobilizing the power of higher education to tackle the grand challenge of sustainability: Lessons from novel organizational experiments. In review.

Research results demonstrate an effective, low-cost tool for detecting contaminants

Results from a WRRI research study indicate that Fluorescence Spectroscopy is an effective and low cost tool for detecting contaminants in natural water systems. Detection limits were reached that are comparable to those reached by more expensive detection methods. PARAFAC analysis aided in the detection process especially when studying mixtures of different target compounds in solution. Researchers were able to distinguish between the target compounds and other components naturally found in water like DOM.

Conducting liquid-liquid extractions prior to fluorescence further lowered limits of detection.

A cost analysis comparing EPA Method #1698 to that of the Fluorescence Spectroscopy and PARAFAC software method indicates a lower capital cost for the new method which is additionally improved when maintenance and consumable costs are factored in.