Senator George J. Mitchell Center for Environmental & Watershed Research Annual Technical Report FY 2009

Introduction

The Maine Water Resources Research Institute provides a key function to sustain water science in the state through its support of research, graduate studies, and outreach. These fundamental and essential functions would not exist without Congressional authorization and appropriations. The federal money that supports the Water Resources Research Institute is highly leveraged with other funds provided by stakeholders, universities, and researchers. During the FY09 period, the Maine Institute supported seven research projects, including four student-directed projects: (1) Using Fluorescence Spectroscopy as a Rapid, Cost-Effective Method to Monitor and Analyze Low Levels of Pharmaceuticals in Three Maine Rivers; (2) A sequential time-weighted average monitoring approach for monitoring pesticide levels in Maine surface waters; (3) Sustainable water allocation and rule making for Maine's surface waters: Adaptation consideration in a changing climate; (4) Influences of dissolved organic carbon and iron on phosphorus photochemistry in surface waters; (5) Temporal changes of the phosphorus concentration profiles in two Maine lake sediment porewaters using a passive sampling technique; (6) Impacts of White Perch Introductions on Trophic Dynamics: Paleolimnological Record of Zooplankton Grazing and Nutrient Cycling; and (7) Using GC/FT-ICR MS for the Identification of Disinfection By-products. In addition to the Maine Institute's direct Information Transfer activities, three additional information transfer projects were supported: (1) Regional Pilot to Reduce Stormwater Polluting Behaviors through Social Marketing as an Environmental Education Tool in the Bangor Urbanized Area; (2) Conserving Significant Vernal Pools through Collaborative Local Initiatives; and (3) Citizen Science: Solving Groundwater Issues in New England. These projects alone provided support to ten graduate students and two undergraduate students.

The Maine Institute Director, John Peckenham, also serves as the Assistant Director of the Senator George J. Mitchell Center for Environmental and Watershed Research. The Mitchell Center provides the administrative home for the Institute. This structural association greatly 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 15th annual Maine Water Conference was held in March and continues to be a very important regional event for the water community. 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 major supporters, we have been able to address the important water issues in Maine and to bring together diverse interest groups. The Water Resources Research Institute's affiliation with the Mitchell Center gives us the ability to support small projects that address important local needs. It also provides us leverage to develop and attract funding from other agencies. This program is strongly supported by our Vice-President for Research who has contributed $50,000 to the 104b research projects. In FY09, the Maine Institute had projects funded by municipalities, state agencies (e.g. Department of Inland Fish and Wildlife, 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 Institutes supports research and information transfer projects using 104b funds. 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 (out of state reviewers are required). The full Research Advisory Committee (12 members) reads the proposals and reviews to provide the Institute Director with a 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 directly involving students. Investigators are encouraged to collaborate with state and federal agencies and to seek additional contributions for their projects.

Starting in FY09, a special student competition was initiated to fund summer research. A call for proposals is issued in March and reviewed by the Research Advisory Committee Executive Committee. Student project budgets are allowed up to be up to $5,000 and a total of $20,000 is allocated for this program. Response to this student-centered program has been strong and it will be continued in FY10.

Using Fluorescence Spectroscopy as a Rapid, Cost-Effective Method to Monitor and Analyze Low Levels of Pharmaceuticals in Three Maine Rivers.

Basic Information

Title:	Using Fluorescence Spectroscopy as a Rapid, Cost-Effective Method to Monitor and Analyze Low Levels of Pharmaceuticals in Three Maine Rivers.
Project Number:	2009ME171B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	2nd
Research Category:	Water Quality
Focus Category:	Water Quality, Toxic Substances, Methods
Descriptors:	None
Principal Investigators:	Howard Patterson, Adria Elskus, Jim Killarney, Lawrence A LeBlanc, John M. Peckenham

Publications

There are no publications.

Progress Report for USGS WRRI Project # 2008ME171B

James Killarney

Project Title: Using a Novel Fluorescence Method as a Rapid, Cost-Effective Way to Monitor Low Levels of Pharmaceuticals in Three Maine Rivers.

Work Completed:

- Collected water samples (November, March-May) from the St. John (Fort Kent), Penobscot (Bangor) and Stillwater (Orono) rivers and created excitation emission (EEM) spectra for each sample.
- Created concentration dependent models using parallel factor analysis (PARAFAC) for triclosan in de-ionized water
- Created concentration dependent standard curves using PARAFAC for 17α-ethinylestradiol in de-ionized water and spiked environmental samples.
- Run synchronous scan fluorescence spectroscopy on a mixture of 17α-ethinylestradiol, triclosan and caffeine.

Work Planned for remainder of funding (September, 2010):

- Continue water sampling from and EEM spectra generation of each river site.
- Collect drinking water samples (pre/post treatment) and perform EEM/PARAFAC analysis on samples.
- Enter EEM data from sampling sites into PARAFAC concentration models to detect potential presence of trace contaminants.
- Create PARAFAC models and evaluate EEM data for the following emerging PPCP contaminants: trenbolone, carbamazepine and bisphenol A.

Additional Funding:

Additional funding has been procured using the data generated in this study:

- Maine Technology Institute (MTI) seed grant SG4285 ($10,050): 10 months
    - Develop EEM/PARAFAC analysis into a prototype for potential commercial applications.
    - Provide salary for additional graduate student (summer 2010) and 2 undergraduate students (summer and fall 2010) to work on this project.

Presentations:

Fluorescence Spectroscopy as a Rapid, Cost-Effective Method to Monitor and Analyze Low Levels of Pharmaceuticals and Personal Care Products in Environmental Water Samples. June 11, 2009. **Poster**. Society of Environmental Toxicology and Chemistry (SETAC) North Atlantic Chapter 15th Annual Meeting.

Fluorescence Spectroscopy as a Rapid, Cost-Effective Method to Monitor and Analyze Low Levels of Pharmaceuticals and Personal Care Products in Environmental Water Samples. September 23, 2009. **Oral**. National Ground Water Association (NGWA) 7th International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water.

Fluorescence Spectroscopy as a Rapid, Cost-Effective Method to Monitor and Analyze Low Levels of Pharmaceuticals and Personal Care Products in Environmental Water Samples. October 20, 2009. **Oral**. 2009 International Symposium on Pharmaceuticals in the Home and Environment.

A sequential time-weighted average monitoring approach for monitoring pesticide levels in Maine surface waters.

Basic Information

Title:	A sequential time-weighted average monitoring approach for monitoring pesticide levels in Maine surface waters.
Project Number:	2009ME172B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	second
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Toxic Substances, Surface Water
Descriptors:	None
Principal Investigators:	Aria Amirbahman, Lucner Charlestra, David Courtemanch

Publications

There are no publications.

THE UNIVERSITY OF MAINE
ECOLOGY AND ENVIRONMENTAL SCIENCES (EES) PROGRAM
PROJECT ACTIVITIES AND EXPECTED DELIVERABLES
By Lucner Charlestra

PROJECT TITLE: A Sequential, Time-weighted Average Approach for Monitoring Pesticide Levels in Maine Surface waters.

PROJECT OBJECTIVES

This project aims at using a passive sampler, the Polar Organic Chemical Integrative Sampler (POCIS) to sample pesticides in surface waters near blueberry fields in Washington and Hancock Counties (ME). The specific objectives are:

1. To conduct laboratory studies in order to determine sampling rate values for the POCIS in quiescent and turbulent conditions for hexazinone, phosmet, chlorothalonil and propiconazole. These sampling rates will allow for the estimation of pesticide concentrations in water.
2. To perform stream sampling designed to compare pesticide concentrations generated by the POCIS and standard water column samples.

SUMMARY OF PROJECT ACTIVITIES

Method Optimization

The first step toward pesticide detection and quantitation was the optimization of analytical methods for the target compounds from spiked water and POCIS samples in the laboratory. The procedure for water samples was inspired from EPA methods 3500, 507, 508, 525.2, and 8141A. Extraction from the POCIS sorbent was carried out according to the SOP provided by the manufacturer (EST laboratory,Saint Joseph, MO). These methods include a sample extraction phase and quantification of the analytes using gas chromatography mass spectrometry (GC/MS). A selected ion monitoring (SIM) method allowed satisfactory chromatographic separation and detection of all four pesticides.

Laboratory calibration experiments

A calibration experiment was conducted to determine the sampling rates (R_s) of the pesticides by the POCIS device. The experiment consisted of stirred beakers containing 1 L of water (and other salts to buffer P^H and adjust ionic strength) with the following treatments in duplicates:

- deionized (DI) water+ pesticide+ 1 POCIS
- natural unfiltered water (Pleasant River)+pesticide+1 POCIS
- natural filtered water+pesticide+ 1 POCIS
- control (DI water+ pesticide only)

This experiment yielded sampling rates in unfiltered river water of 0.72, 0.63, 0.49 and 0.90 Ld^{-1} for chlorothalonil, propiconazole, hexazinone and phosmet, respectively (see the December 2008 progress report). A static exposure experiment was carried out in beakers containing 1 L of stagnant DI water (no stirring) with the same chemical composition as the stirred exposure. The aim was to generate R_s values more applicable to stagnant water bodies in the field (such as some bogs and brooks in the study areas). In order to measure Rs in a setting that is closer to hydrodynamic conditions in rivers, a flow-though experiment was conducted in a 10 L fish tank. Tap water and the solution of test analytes were pumped into the exposure tank at known and control rates to maintain a constant concentration of the pesticides throughout. POCIS devices were sequentially deployed in, and removed from the fortified water over a 21 day- period. Further details about these experiments will be reported in the papers and the doctoral thesis.

<u>Field work</u>

In the summer of 2008, we conducted a proof of concept study aimed at demonstrating that the POCIS can sequester the pesticides used in the study area. Many sites located in the main stems and tributaries of Pleasant and Narraguagus rivers were explored in collaboration with the staff of the Bureau of Sea-run Fisheries and Habitats as potential deployment sites. These sites were selected on the basis of their proximity to blueberry fields and free public access. The actual field survey was carried out in Pork Brook (PB), Bog Brook (BB), Colonel Brook (CB), Great Fall (GF) and Sodom Brook (SB) from July 10 to August 9 2008. POCIS devices were deployed and retrieved sequentially (within one week intervals). The aim was to compare pesticide concentration patterns measured with POCIS with those found with grab samples. Preliminary results showed that all the pesticides but hexazinone had concentrations below the limit of quantitation (0.1µgL-1) during the sampling period (see the December 2008 progress report for more details).

In the summer of 2009, the field sampling was carried out in the two sites on the Narraguagus River (Donald Backman Trail (NDB) and Little Fall station (LFS)) and at Sodom Brook (same sites as the 2008 field season). The Narraguagus sites would provide information on the POCIS performance in a larger river system, whereas the repetition at the Sodom Brook would evaluate the temporal variation in contamination in that particular site, while testing the reproducibility of the similarity in sampling patterns found with POCIS and water samples.

<u>Project deliverables</u>

Achieved and expected project deliverables include:

- A poster presented at the "EPA 2007 National Forum on Contaminants in Fish" from July 23 to 26, 2007 in Portland (ME), entitled: "The Use of Passive Samplers (SPMD and POCIS) for Monitoring Dioxin and Pesticide Levels in Maine Surface Waters"
- Two undergraduate students trained in the design of laboratory and field experiments and the analysis of pesticides in water and POCIS samples.
- Two research papers to be published (see outlines below)
- Luner Charlestra's doctoral thesis to be written (see outline below)

PAPER 1 OUTLINE

Journals: Environmental Toxicology and Chemistry/ or Chemosphere

TITLE:

Calibration of the Polar Organic Chemical Integrative Sampler (POCIS) for the Monitoring of Pesticides in Water.

Abstract

INTRODUCTION

The rationale for monitoring the four mostly used pesticides (e.g. chlorothalonil, propiconazole, hexazinone and phosmet) on blueberries in Maine will be discussed from a toxicological standpoint. The use of the POCIS device, as opposed to biomonitoring and active (grab) sampling for different applications will be reviewed. The importance of laboratory calibration experiments to approximate concentrations in the field will be discussed. The emphasis will be put on the fact that only a few passive sampler studies investigated the impact of natural organic matter (NOM) on the freely dissolved concentrations of contaminants, thus on their sampling rates (Rs) by these devices in water. Given the complexity and unique nature of NOM molecules, the use of river water (along with synthesized reagent water) to derive the sampling rates in this study will be justified. Also, I will discuss the relevance of deriving the Rs in different hydrodynamic conditions (e.g. static (stirred and quiescent) and flow-though exposures) in relation to conditions in the field.

PASSIVE SAMPLING THEORY

MATERIALS AND METHODS

Chemicals and reagents

Polar organic chemical integrative sampler

Laboratory calibration experiments

Static freshwater exposures

Flow-through freshwater exposure

Extraction procedures

Water extraction

POCIS extraction

Instrumental analysis and quality control (QC)

Data analysis

RESULTS AND DISCUSSIONS

Physicochemical properties of the pesticides

Effects of natural organic matter

Effects of hydrodynamics

Acknowledgement

PAPER 2 OUTLINE

Journals: Environmental Toxicology and Chemistry/ or Chemosphere

TITLE:

Monitoring pesticide contamination of Maine Surface Waters using Sequential Active and Passive Water Sampling.

Abstract

INTRODUCTION

The findings of different surveys that showed increasing pesticide contamination of water resources in the United States will be reported. The rationale for monitoring the four mostly used pesticides (e.g. chlorothalonil, propiconazole, hexazinone and phosmet) on blueberries in Maine will be discussed from a toxicological standpoint. The use of passive sampling (e.g. POCIS device), as opposed to biomonitoring and active (grab) sampling for different applications will be reviewed. The importance of the sequential deployments (at one week intervals) of the POCIS device will be sustained by the need to capture peak concentrations of pesticides driven in part by watershed hydrology (runoff) that can trigger spikes as short as 48h.

MATERIALS AND METHODS

Stream sampling

Pesticide extraction and analysis

Quality control

Estimation of ambient water concentration

RESULTS AND DISCUSSION

Physicochemical properties of the pesticides

Comparisons of detections and concentrations

Trends in detections and concentrations

Acknowledgement

DOCTORAL THESIS OUTLINE

TITLE:

A Sequential, Time-weighted Average Approach for Monitoring Pesticide Levels in Maine Surface waters.

Sustainable water allocation and rulemaking for Maine's surface waters: Adaptation consideration in a changing climate

Basic Information

Title:	Sustainable water allocation and rulemaking for Maine's surface waters: Adaptation consideration in a changing climate
Project Number:	2009ME176B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	2
Research Category:	Climate and Hydrologic Processes
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Shaleen Jain, David Courtemanch, David D. Hart

Publications

There are no publications.

Elsevier Editorial System(tm) for Journal of Environmental Management
Manuscript Draft

Manuscript Number:

Title: Past climate, future perspective: An exploratory analysis using climate proxies and drought risk assessment to inform water resources management and policy in Maine, USA

Article Type: Research Paper

Keywords: Water allocation; water policy; climate; drought; ecosystem services; tree-rings

Corresponding Author: Prof. Shaleen Jain, Ph.D.

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Order of Authors: Avirup Sen Gupta; Shaleen Jain, Ph.D.; Jong-Suk Kim

Past climate, future perspective: An exploratory analysis using climate proxies and drought risk assessment to inform water resources management and policy in Maine, USA

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ABSTRACT

In recent decades, significant progress has been made toward reconstructing the past climate record based on environmental proxies, such as tree-rings and ice core records. However, limited examples of research that utilizes such data for water resources decision-making and policy exist. Here, we use the reconstructed record of Palmer Drought Severity Index (PDSI), dating back to 1138AD to understand the nature of drought occurrence (severity and duration) in the state of Maine. This work is motivated by the need to augment the scientific basis to support the water resources management and the emerging water allocation framework in Maine (Maine Department of Environmental Protection, Chapter 587). Through a joint analysis of the reconstructed PDSI and historical streamflow record for twelve streams in the state of Maine, we find that: (a) the uncertainties around the current definition of natural drought in the Chapter 587 (based on the 20th century instrumental record) can be better understood within the context of the nature and severity of past droughts in this region, and (b) a drought index provides limited information regarding at-site hydrologic variations. To fill this knowledge gap, a drought index-based risk assessment methodology for streams across the state is developed. Based on these results, the opportunities for learning and challenges facing water policies in a changing hydroclimate are discussed.

Keywords: Water allocation, water policy, climate, drought, ecosystem services, tree-rings

1. Introduction

Located in the northeastern region of the United States, the state of Maine is known for its abundant water resources. In this “water-rich” state, the average annual precipitation (in its three climate divisions) ranges between 40-46 inches. However, a prolonged drought at the turn of the 21st century (1999-2003) exemplified the widespread nature of the statewide socioeconomic impact of drought, including $32 million in crop losses (Maine Agricultural Water Management Advisory Committee, 2003; Schmitt, 2003). Detrimental impacts of the drought on Maine’s natural resources and ecosystems were likely significant, however, not well understood. Focusing events (Pulwarty et al., 2007), such as the recent multiyear drought, provide a window in to the vulnerability of Maine’s people, ecosystems, and economy to hydroclimatic extremes.

Proactive management and planning within a water allocation framework has been viewed as an important step towards the long-term sustainability of water resources in Maine. To this end, in 2006, the state of Maine completed a nearly decade-long rulemaking process that culminated in the promulgation of a sustainable water use policy (MDEP, 2009). A major goal of this policy is to balance the human and ecological use of water by limiting withdrawals from the water bodies for agriculture and industrial purposes, and community use. A key tenet of this water allocation framework concerns the provision of seasonally varying aquatic baseflows that mimic the natural flow regime and are likely to support ecosystem function and health. The limits on water withdrawals prevent repeated low flow occurrences stemming from excessive withdrawals, thus supporting both ecosystem and water quality objectives. Maine Department of

Environmental Protection (MDEP) Chapter 587 allows a variance from limits on water withdrawal from surface water bodies during droughts, when withdrawals may continue to occur despite unmet water quality and aquatic base flow thresholds. These variances aid Community Water Systems that rely on Maine's rivers and lakes. According to MDEP "***Natural drought condition*** *means moisture conditions as measured by the Palmer Drought Severity Index with values of negative 2.0 or less* (MDEP, 2009)." While the PDSI threshold of -2 and more severe droughts have rarely occurred in the 20th century, two considerations that motivate this study are:

1. The range of variability seen in limited-length hydrologic and climate records provide a snapshot (depending on the length of the observational record) of the natural envelope of climate in a particular region; as a result, "hydroclimatic surprises" may occur, especially in cases where the observational record fails to represent the range of variability. Such events can prove to be major detriments to effective implementation of management and policy in water resources systems. In this context, to what extent is the 20th century record of Maine's PDSI consistent with the longer-term variability seen in a multi-century climatic reconstruction? To date, limited examples of use of hydroclimatic reconstructions to inform water policy and management exist (for example, Rice et al. 2009). In this study, we use the reconstructed record of Palmer Drought Severity Index (PDSI), dating back to 1138AD to understand the nature of drought occurrence (severity and duration) in the state of Maine.

2. Given that droughts exhibit substantial spatial and temporal variability, an analysis framework that allows translation of statewide PDSI index to watershed-scale estimates of hydrologic risk are likely to benefit water resources management and decision-making.

In this study, we pursue a joint analysis of the historical record of the PDSI and streamflow across Maine and develop a probabilistic methodology to assess local hydrologic risk.

2. Background

This section describes the motivation and details regarding the water allocation framework, Chapter 587, in Maine. A limited discussion of the drought impacts on aquatic ecosystems is also presented.

2.1 In-stream Flows and Lake and Pond Water Levels standards in Maine

The state of Maine, recognizing the value of its natural resources, has pursued environmental protection efforts in the past decades (UCS, 2007). Many of the statutes that have been enacted by the Department of Environmental Protection (DEP) over the last fifty years acknowledge the importance of natural ecosystem and maintaining water qualities of all its water bodies. Recently, DEP developed *"The In-stream Flows and Lake and Pond Water Levels rule"* which established river and stream flows and lake and pond water levels to protect natural aquatic life and other designated uses in Maine's waters (MDEP, 2009). Flow management seeks to provide natural variation of flow (seasonal aquatic base flows, or other seasonally variable flows), thus affording protection to aquatic life resources and maintaining water quality standards. Important considerations such as, alteration of natural flow or water levels (non-tidal fresh surface water) through direct or indirect withdrawal, removal, diversion or other activity are included (MDEP, 2009). Classified state waters, such as, rivers, streams, brooks, lakes and ponds are included. Knowledge concerning droughts is an important input in to the community water resources planning and in the allocation of available water supplies. The Chapter 587 (MDEP, 2009) defines "natural drought condition" as *moisture conditions as measured by the Palmer Drought Severity Index with values of negative 2.0 or less."* The chapter notes, *"Whenever natural drought conditions, in combination with Community Water System use, cause the applicable instream flow or water level requirements of this chapter to not be maintained, the Community Water System may continue to withdraw water for public need subject to any conditions the Department may impose through the issuance of a variance pursuant to 40 CFR 131.13 (2006). Such variances may last for the duration of the drought condition and shall protect all water quality standards to the extent possible, recognizing the combined effects of a natural drought and the need to provide a safe, dependable public source of water."* Thus, the recent promulgation of the water allocation rulemaking in the state of Maine seeks to incorporate adequate instream flow allocations to support ecosystem services, while meeting the allocation needs for agriculture, municipal and industrial sectors. While this is a significant step that will likely catalyze similar rulemaking in other states, the long-term prospects of desirable outcomes in some respect also hinge upon the hydroclimatic thresholds (for example, PDSI) and variances noted in the rulemaking/allocation framework.

2.2 Drought impacts on ecosystems

Natural droughts stem from lack of precipitation and result in surface runoff deficits and receding groundwater level (Lake et al., 2008); as a result, have a profound adverse effect on the natural life, such as loss of quality and quantity of native flora and fauna. From a riparian ecosystem health standpoint, the lower levels of runoff impact the lateral connectivity in streams. Shallow areas tend to become riffles and runs (Stanley et al., 1997) and pools form in the deep areas. Thus the longitudinal fragmentation constrains the movement of nutrients, planktons, fishes, and other aquatic species. Species with sedentary lifestyles and limited capacity for movement suffer high mortality by getting trapped in riffles; however, pool dwellers survive with little mortality (Golladay et al. 2004, Lake et al. 2008). Mobile species, such as fish and other invertebrates may move into the pool (Magoulick, 2000; Lake, 2008) or as drought develops may emigrate into upstream or downstream of the river based on the landscape of drought progression. In pools, large populations reside in small amount of water. High concentration and density of different species may increase the intra- and interspecies interaction, such as predation and competition (Lake et al., 2003). Due to disruption of longitudinal flow, transport of nutrients and other organic matter deceases significantly (Dahm et al., 2003). Additionally, standing water in the pools may lead to algal blooms (Freeman et al., 1994; Dahm et al., 2003) with resulting stresses on oxygen availability in pools. In this manner, high density, crisis of food availability, warm temperature, low oxygen level creates unhealthy and inhospitable condition in the water and may lead to diminishing fish populations and those of other invertebrates (Lake, 2003). During extended droughts, due to the deficit of rainfall, many small streams and tributaries of large rivers dry up. In temperate climates, reproduction of fish that use small gravel streams for breeding decreases significantly (Lake et al., 2008). Overall, droughts can have a strong detrimental impact on the aquatic ecosystems; thus, a detailed characterization of their frequency and intensity is likely to aid improved management and policymaking to support ecosystem services.

At a location, a definition for natural drought is complicated by the very nature of its severity and duration; at the same time, drought characterization is important for policy setting in water-sensitive sectors. PDSI is a widely used index for drought monitoring and characterization. Efforts to provide regular updates and forecasts for PDSI and other related variables appear to be a key priority for the National Integrated Drought Information System (www.drought.gov) in the United States, and have the potential to inform water allocation and use. An example of the use of PDSI information is that of the natural drought threshold used in Maine's Chapter 587. The analyses presented in the following sections explore the variations in the frequency of natural drought over the past centuries (based on the reconstructed PDSI), incidence of multiyear droughts, and how the 20th century record fits into the drought statistics based on a eight century-long record. Furthermore, we explore the relationship between the PDSI index for the entire state (or a sub-region) and the individual streams that: a. exhibit differing sensitivity to drought stress, and b. represent watershed units where community-scale water management and decision-making is pursued. The aspiration to utilize a reconstructed PDSI records promises significant, new information to inform water resources management and policy. However, comparisons between reconstructed PDSI and the 20th century observations would be valid if the reconstructions were perfect. That is, the tree-ring width variations have a one-to-one correspondence with the PDSI variability. As is well known, that is never the case. Environmental proxies (in this case, tree-rings) explain only a portion of the variance of the historical data. This raises an important concern regarding careful interpretation and framing of the insights gained from various analyses in a manner that promotes appropriate use of the new information. Consequently, the use of such information may be limited to qualitative assessment and discussion regarding various management and policy options. To this end, the next section provides a detailed description and discussion of the reconstruction and the range of factors that influence these proxy records.

3. Data

3.1 Reconstructed Palmer Drought Severity Index (PDSI)

In this study, we used Cook et al. (2004) reconstructed record of PDSI for the state of Maine dating back to 1138 AD. The Palmer Drought Severity Index (PDSI) has been the most commonly used and most effective drought index in the United States (Palmer, 1965). PDSI reflects variability in precipitation, air temperature, and local soil moisture, along with prior information of these measures, to determine the dryness or wetness of a particular region. PDSI value generally varies from -6 to +6. A normal or neutral value of 0 is used. Drought severity is represented as: moderate drought (-2), severe drought (-3), and extreme drought (-4).

In the recent years, tree-ring based reconstructions of the streamflow in semi-arid regions have provided important details to support water resources management (for example, Woodhouse and Lukas, 2006). The availability of water in arid or semi-arid regions is well captured by tree-ring growth. In moist and wetter climates, tree-rings are less sensitive and sometimes the growth is not limited by the moisture conditions; however, while calibrating, nearly half of the hydrologic variability of Maine’s PDSI was explained by the tree-ring for years 1928-1978 (data sources, description and quality are discussed in the next section). Normally, wide rings and narrow ring widths correspond to above and below average rainfall respectively. Cumulative precipitation shows high correlation with annual streamflow and also exerts a strong influence of tree-ring growth.

3.2 Reliability of the Reconstructed PDSI Data

Although the proxy records provide a general history of drought variability in Maine, one might question the fidelity of the reconstructed PDSI data based on tree-rings. To this end, Cook et al. (2004) use a suite of statistical metrics to verify the association between the actual and estimated PDSI. The updated version of PDSI datasets (available online at: www.ncdc.noaa.gov/paleo/pdsidata.html; Reconstruction of Past Drought Across North America from a Network of Climatically Sensitive Tree-Ring Data) contains a network of 286 grid points (in 2.5° X 2.5° grids) over North America for both instrumental and reconstructed data. We use the grid point number 270 in our analysis. Cook et al. (2004) provide calibration/verification statistics such as: Calibration R^2, Verification R^2, Verification reduction of error (RE), Verification coefficient of efficiency (CE). The common time period between the chronologies and instrumental PDSI records were divided in to two time series: (a) the years 1928-1978 were used to calibrate the model and, (b) the years 1900-1927 were for reconstruction verification. Calibration R^2 and Verification R^2 measure the percent PDSI variance in common between actual and estimated PDSI at each grid point over the calibration period and verification period respectively. These statistics range from 0 to 1.0, where 1.0 indicates perfect agreement between instrumental PDSI and the tree-ring estimates. Lower values of calibration/verification R^2 indicate increasing failure to estimate PDSI from tree-rings. In the case of the provided dataset, the median Calibration R^2 over the entire 286 grid-points is 0.514, indicating that more than half of the PDSI variance is being explained by tree-ring chronologies. Verification R^2 is never exceeds Calibration R^2. Here, the median Verification R^2 drops somewhat from the calibration R^2 (as expected) to 0.445. In the case of reconstructed climatic data, such calibrated variance (Calibration R^2) is considered quite acceptable and small differences between the Verification R^2 and Calibration R^2 indicate satisfactory levels of reliability. RE and CE statistics have been used extensively to test the skill of models in meteorological forecasting. RE assesses the skill of the reconstruction within the verification period, in comparison to the estimates in calibration period for the means of the observed data. The basic difference between RE and CE is that CE uses the verification period mean for assessing the skill of the estimates and RE uses the calibration period mean (Lorenz, 1956; Fritts, 1976; Cook et al. 1999; Woodhouse and Brown, 2001). Both RE and CE have a theoretical range of $-\infty$ to 1.0. Positive values indicate that a reconstruction contains some skill over that of climatology. In other words, there is some information in the reconstruction. In this dataset, the median RE and CE over all 286 grid-points are 0.419 and 0.357 respectively. RE is always greater than CE (Cook et al., 1999). Here both RE and CE are strongly positive which indicates significant reconstruction skill over the PDSI grid. Thus, it is quite evident that overall North American PDSI grid is well calibrated and verified.

The reconstruction performance statistics for the grid over Maine are available separately. For Maine's grid-point (Grid-point no: 270, Latitude: 45.0^{o} N, longitude: 70.0^{o} W), statistics such as: Calibration R^2, Verification R^2, RE, CE values are 0.474, 0.244, 0.211, and 0.165 respectively. In dendrochronology, calibrated variance of 0.474 is considered to be reasonably good (explaining almost half of the variation), however, this information must be discussed alongside any analysis and interpretation. Verification R^2 is 0.244 compared to a value of 0.474 in the calibration period. Verification R^2>0.11 is statistically significant at the 1-tailed 95% level using a 28-year verification period (Cook et al., 2004). Significant positive magnitudes of RE and CE imply meaningful reconstruction skill for the abovementioned grid-point.

While the reconstructed PDSI provides long-term estimates for drought frequency and severity, it is also evident that only a fraction of the observed variance is explained. Given this, a key consideration is to assess how the spatial extent of the droughts varies when a persistent event occurs. The strength and spatial extent of drought signals were examined by correlating the yearly summer PDSI at each grid-point with the yearly summer PDSI for Maine (Grid-point no 270; Cook et al., 2004), over four different 100-year periods (**Figure 1**). The correlation pattern is then mapped out. In a particular century, if a grid-point contains more than 50 missing values for a particular century then that point is not considered for correlation calculation and placed as a gray circle on the map.

An important goal of this investigation is to examine the spatial pattern of the correlation in the twentieth century when the instrumental data are available, and then compare it with maps of other centuries when only the reconstructed PDSI data are estimated. The 20th century correlation map shows that the PDSI grid point for Maine is strongly correlated with its neighboring grid points, especially points in the New England and Middle Atlantic region in the United States and neighboring Quebec, Canada. Strong to moderate correlation coefficients were also found in the East Central region; no significant correlations were found for Central and Pacific region. A strong correlation with neighboring grid points is the most significant characteristics of 20th century correlation map—a pattern that is also replicated in the past centuries. However, in 17th and 19th century, this region was more widespread than in 15th century. This implies that the hydroclimatic variability in Maine and its surrounding region shows a distinctly regional character with some variations on centennial time scales. This is also consistent with the notion that persistent and severe droughts are likely to occur on broader spatial scales and that the attendant drought variability in Maine is consistent with the regional-scale variations.

3.3 Historical Streamflow Records

Daily streamflow data from twelve stream gauges in Maine, USA are analyzed in this study (see Table 1 for details). Stream gauging stations are selected based on the availability of a serially complete dataset spanning for the 1951-2003 period. Daily mean stream flow data are obtained from the U.S. Geological Survey Hydro-Climatic Data Network for the United States (U. S. Geological Survey, 2010). This network includes the gauges whose watersheds are relatively free of human influences such as regulation, diversion, land-use change, or excessive groundwater pumping.

4. Drought Variability and Hydrologic Risk in Maine

4.1 Drought in the Twentieth Century

The four year long drought of 1999-2002 was the most severe and damaging over the historical record (Lombard, 2004). The drought episode evolved from "widespread" during the four year period and "severe" in 2001-2002. Lombard (2004) notes that the major impacts of the drought included: *"(1) thirty-five public-water suppliers, including 8 large community systems, were affected severely (Andrews Tolman, Maine Drinking Water Program, written commun, 2003); (2) approximately 17,000 private wells in Maine went dry in the 9 months prior to April 2002 (Maine Emergency Management Agency, 2002); (3) more than 32 million dollars was lost in crops in 2001 and 2002 and some growers of wild blueberries recorded crop losses of 80 to 100 percent (Maine Agricultural Water Management Advisory Committee, 2003)."* The 7-year long, 1963-1969 drought is the most severe case in the historical record in terms of its duration (Lombard, 2004). The 1978 drought in Maine was mild, however, the low-flow recurrence intervals reached the 35 year return period levels (Lombard, 2004). Observational records show that in each case of multiyear drought, only one or at most two years had a PDSI value below -2. However, consecutive dry years with negative PDSI less severe than the -2 threshold have the potential to cause significant damage to agriculture, forest life, mankind and ecosystem. Such droughts, mild yet prolonged, may have significant cumulative impact, however, do not meet the severity threshold of -2. Therefore, a detailed characterization of severity and duration of droughts is an important consideration for adaptive management and policy implementation for future droughts in the changing climate.

4.2 Long-term Drought Variability in Maine

Using a fifty-year moving window, we analyzed the frequency of dry (PDSI < -2) and wet (PDSI > 2) years during the 1138 to 2003 period (**Figure 2**). The Fourteenth century was a predominantly wet period. There were only one or two dry years and up to eight wet years were found in every fifty-year period during that time window. But at the end of thirteenth and in 14th century, frequency of dry years gradually increased and fluctuated between four and six throughout the century. Number of dry years rose during the 17th and 18th century and number of wet years decreased during that time period. Six to eight dry years were observed while one to three wet years occurred during the seventeenth and eighteenth century period. Subsequent periods show fluctuations consistent with a variable hydroclimate. Based on the unusually wet and dry year counts, the 20th century PDSI fluctuations in Maine appear to be among the wettest (PDSI > 2) and least dry (PDSI < -2) compared to the remainder of the multi-century record. This analysis provides an illustrative example of the temporal fluctuations and the dynamic range of drought variability in Maine. Dramatically different wet and dry period frequency in the paleoclimatic record as contrasted with the 20th century instrumental record illuminate the opportunity to use select historical periods are dry, wet, variable, persistent hydrologic regime scenarios that capture a representative set of drought severity and duration statistics. In discussions regarding environmental sustainability, the use of appropriate scenarios is a critical starting point for discussion within a diverse stakeholder setting. Within the context of droughts in Maine, the prospect of using historical drought statistics, appropriately incorporating the uncertainty, and pursuing adaptive management and options analyses (with water allocation and ecosystems services as the key objectives) can provide valuable insights in to the vulnerabilities and also promote proactive exploration of strategies for coping and adaptation.

During the summer 2001 drought period, water withdrawal was higher than the safe yield in the coastal regions of Maine, coupled with an increased water demand stemming from seasonal tourism and development (Schmitt et al., 2008). Proactive planning to mitigate economic, societal and ecosystems impacts resulting from such drought events is critical. On the one hand, the recent drought was a rare event when viewed against the observational record. On the other hand, as seen in the PDSI reconstructions, a scenario where the frequency of natural droughts increases up to six/eight dry years in every fifty years period is likely to have lasting detrimental impacts on communities, ecosystems, and economy.

MDEP recommends negative two or below as the threshold of natural drought condition. Considering this definition, multi-year droughts are rare in the 20th century observational record (**Figure 3**). However, if we consider a less severe PDSI threshold (such as -1.50, -1.00 or below), a number of multi-year dry periods are evident. Taking the -1.50 or below as a threshold, we identified one 4-year, three 3-year and a number of 2-year droughts in this area during the 20th century. Considering -1.00 or below as a threshold, we find two drought events of five years or longer duration, six 4-year drought and large numbers of 3-year and 2-year droughts in Maine. The analysis of frequency and duration discussed above points to the importance of identifying and developing triggers in drought plans that recognize and respond to prolonged moderate droughts (less severe than the natural drought threshold) in a timely manner. In some respect, the above discussion underscores the need to broaden the definition and metrics for drought monitoring and response. Drought monitoring and forecast products (for example, PDSI or Standardized Precipitation Index) are generally available as area averaged (state or climate division) indices. A related challenge is that of understanding the relationship between the drought indices and the watershed-scale hydrologic variability. The following discussion considers this need and develops an empirical framework that relates PDSI to the streamflow.

4.3 Ascertaining Local Hydrologic Risk Conditioned on the Statewide Drought Condition

Localized estimates of hydrologic risk, conditioned upon the statewide PDSI observation or forecast, provide usable information to water managers and policy makers. Figure 4a shows the empirical probability distribution for PDSI during three century-long periods. To the extent that PDSI and watershed hydrologic variations are linked, the attendant variability in the PDSI statistics capture the nonstationarity in historical records, also evident in the results from a moving window analysis (Figure 2). We used a nonparametric probability density estimation approach to determine the joint probability density of the annual statewide PDSI and mean annual streamflow (1951-2003 period) for the aforesaid twelve stream gauges in Maine. Kernel density estimators represent the non-parametric density estimators that are widely used in theoretical and applied statistics (Bowman and Azzalini, 1997). In comparison to parametric estimators, nonparametric estimators are not restricted to have a specified function form, so as to allow adaptive estimation from data, including departures from linearity. The joint nonparametric probability density estimate (statewide PDSI index and the annual streamflow for the St. John River at Ninemile Bridge, Maine stream gauge) for the 1951-2003 period is shown in **Figure 4b**. The strong linear relationship (correlation = 0.73) highlights that the PDSI index is indeed a useful metric to assess broad-scale hydroclimatic variability. However, the joint relationship also highlights a weakly bimodal nature of the probability distribution, thus providing additional information regarding a flatter probability density distribution for streamflow (Figure 4c, unconditional estimate). The correlation of PDSI index with all the stream gauges in Maine is reported in Table 1.

Based on the 20th century hydrologic data, we further develop conditional probability density function between the statewide PDSI and mean yearly streamflows in different gauges. These relationships are used to develop a watershed-specific characterization of the risk for low flows. We plotted probability distribution function (PDF) for all streamflow data of aforementioned gauge with a solid line, Figure 4(b). Then the conditional distribution of mean annual streamflow (Q) given PDSI ≤ -1 is obtained by an appropriate consideration of the joint probability distribution rescaled by the PDSI probability distribution. Finally, a hydrologic risk estimate is obtained by considering the ratio of exceedance probability based on the conditional distribution to that of the unconditional streamflow distribution. Mathematically,

$$Risk = \frac{P((Q \le Q_{25}) | PDSI \le -1)}{P(Q \le Q_{25})}$$

Here, Q is annual stream flow and Q_{25} the 25th percentile based on the historical record. For a number of stream gauges in Maine, the hydrologic risk associated with flow occurrences below the 25th percentile of the mean annual flow undergoes a nearly two-fold increase upon the inclusion of the conditional PDSI information (Figure 5). The results presented in Figure 5 indicate the conditional hydrologic risk for low flows vary from watershed-to-watershed. This analysis method allows tailoring of information from statewide PDSI conditions to a watershed specific risk assessment. If season-ahead forecast of PDSI are available, then this framework can conveniently translate the forecast to watershed-specific information.

5. Summary and Conclusions

The paleoclimatic reconstructed PDSI record offers the opportunity to analyze the fluctuations in the frequency of wet and dry periods over a multi-century period. A motivating factor for this study is the use of PDSI threshold of -2 in the definition of natural drought for the state of Maine. In this study, we pursued an exploratory analysis of the PDSI index for Maine. We found that the 20^{th} century instrumental record provides important information regarding contemporary drought statistics, including drought events where moderate, yet prolonged droughts have occurred. A multi-century record of PDSI provides an assessment of the broader envelope of hydroclimatic variability in this region, one that is not readily evident in the instrumental record. The historical record provides a number of century-long periods with varying wet and dry period statistics that can be used for scenario analyses and planning. In this study, while exploring the utility of paleoclimatic data we also emphasize the need for a careful consideration of uncertainties regarding use of hydroclimatic reconstructions.

Runoff volumes across watersheds show moderate-to-strong correlation with PDSI. Based on the 20^{th} century hydrologic data we developed joint relationships between the statewide PDSI and water year runoff volume. These relationships are used to develop a watershed-specific characterization of the risk for low flows. These joint probabilistic relationships highlight that the inclusion of PDSI information can benefit local hydrologic risk assessment. Our results suggest the vulnerability of drought (based on statewide PDSI) is not uniform throughout the state, and local characterization methodology shows that elevated hydrologic risk can be quantified for each stream and emergency management agencies can prepare for droughts based on the higher or lower risk values.

Finally, in a changing climate, adaptive management approaches stand to benefit from a careful scrutiny of various aspects of a rule or policy that lends itself to a "set of decisions" to guide the management of natural waters. In increasingly complex and often over-allocated systems, decisions have cascading effects that persist and often have the potential for unintended consequences—consequently, a continual review and, perhaps, inclusion of scientific information is likely to ensure the long-term, intended outcomes for watershed systems.

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FIGURE CAPTIONS

Figure 1. Map of correlations between Maine PDSI records and PDSI records for each grid-point in North America in four different centuries: (a) fifteenth century (1401-1500), (b) seventeenth century (1601-1700), (c) nineteenth century (1801-1900), (d) twentieth century (1901-2000). While large-to-small positive and negative signs indicate high-to-low correlation positive and negative correlation respectively, gray circle highlight the grid points where less than 50 years of data is available during any century.

Figure 2. Frequency of wet and dry years based on a 50-year moving window analysis using Maine's reconstructed PDSI index. This estimate highlights long term variability in climate system and relative "wet" and "dry" conditions in this region. This also shows relative drought frequencies in different time periods in past millennium against a twentieth century (where instrumental data is available) record.

Figure 3. Multiyear drought occurrence using a threshold of PDSI below -1.00 and below -1.50 for the paleoclimatic PDSI (1138-2003) and relative change in the multiyear drought frequencies at two abovementioned thresholds. Drought magnitude is defined as the ratio of severity (consecutive years when PDSI was <-1.0 or <-1.50) and duration. **a.** Number of multiyear drought with duration of 2 years, **b.** Number of multiyear drought with duration of 3 years, **c.** Number of multiyear drought with duration of 4 years, **d.** Number of multiyear drought with a duration of 5 years or more.

Figure 4. a. Scatter plot of PDSI and mean annual streamflow (Q) and contour lines in joint probability distribution using Kernel approach, **b.** probability distribution functions (PDF) for unconditional estimate and also the conditional distribution of mean annual streamflow (Q) given PDSI$\leq$ -1 **c.** Probability distribution of PDSI values in three different time periods 1601-1700, 1501-1600 and 1901 to 2000.

Figure 5. Conditional hydrologic risk is defined as the ratio of the probability for a low flow (lower that the 25th quantile) when PDSI information is included to the unconditional flow estimate.

Figure 1

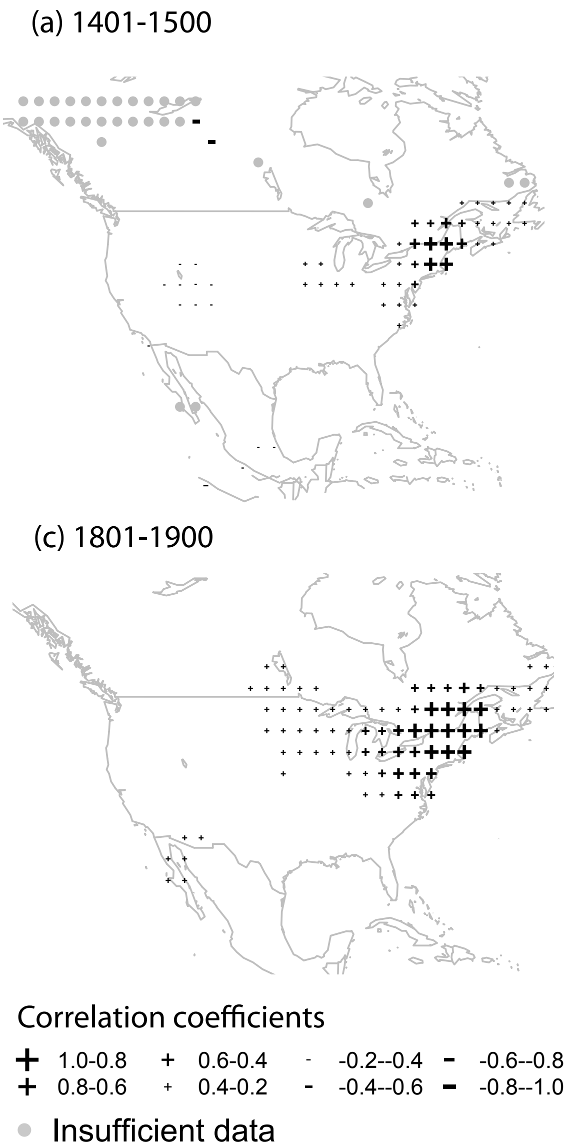
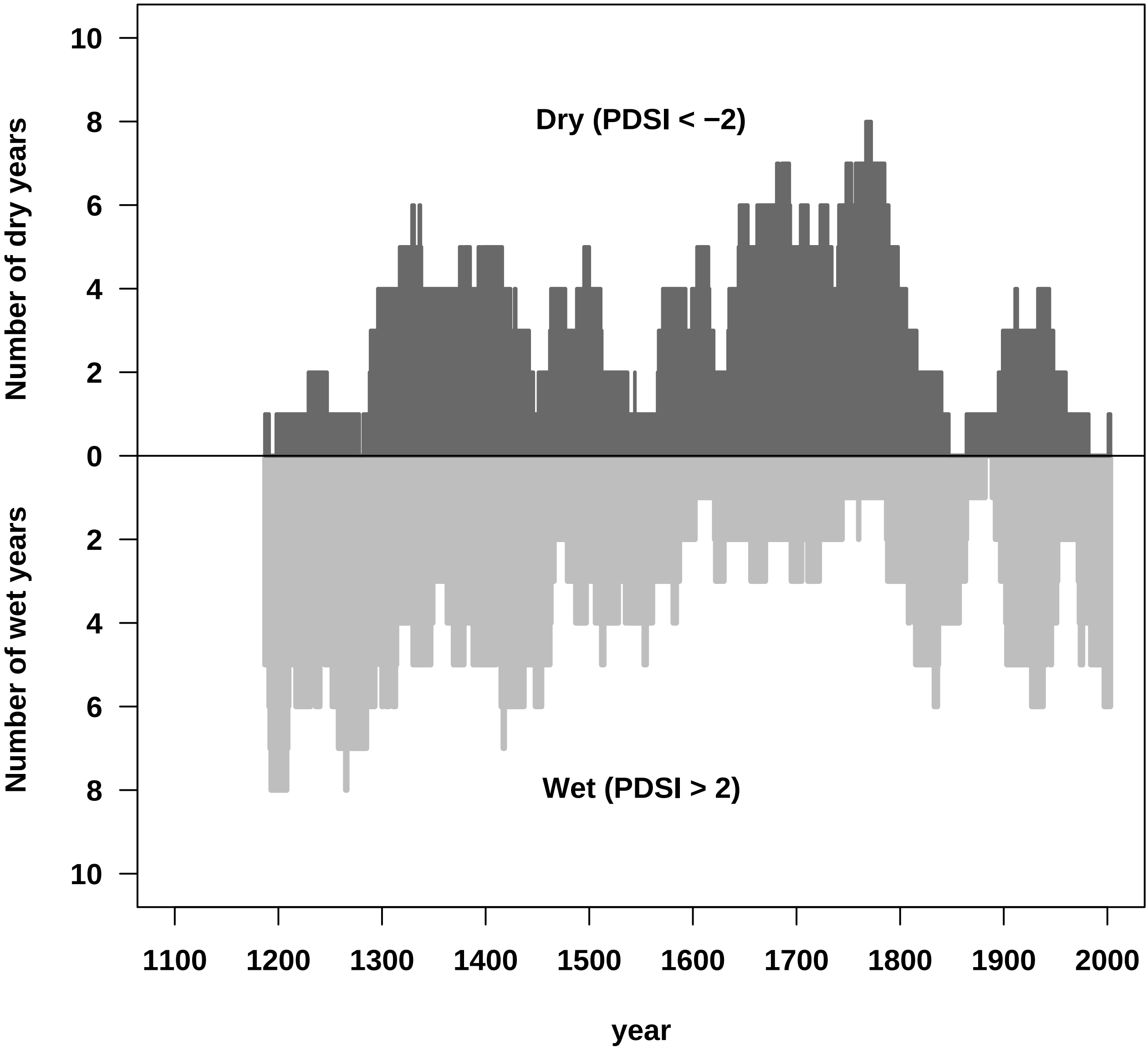
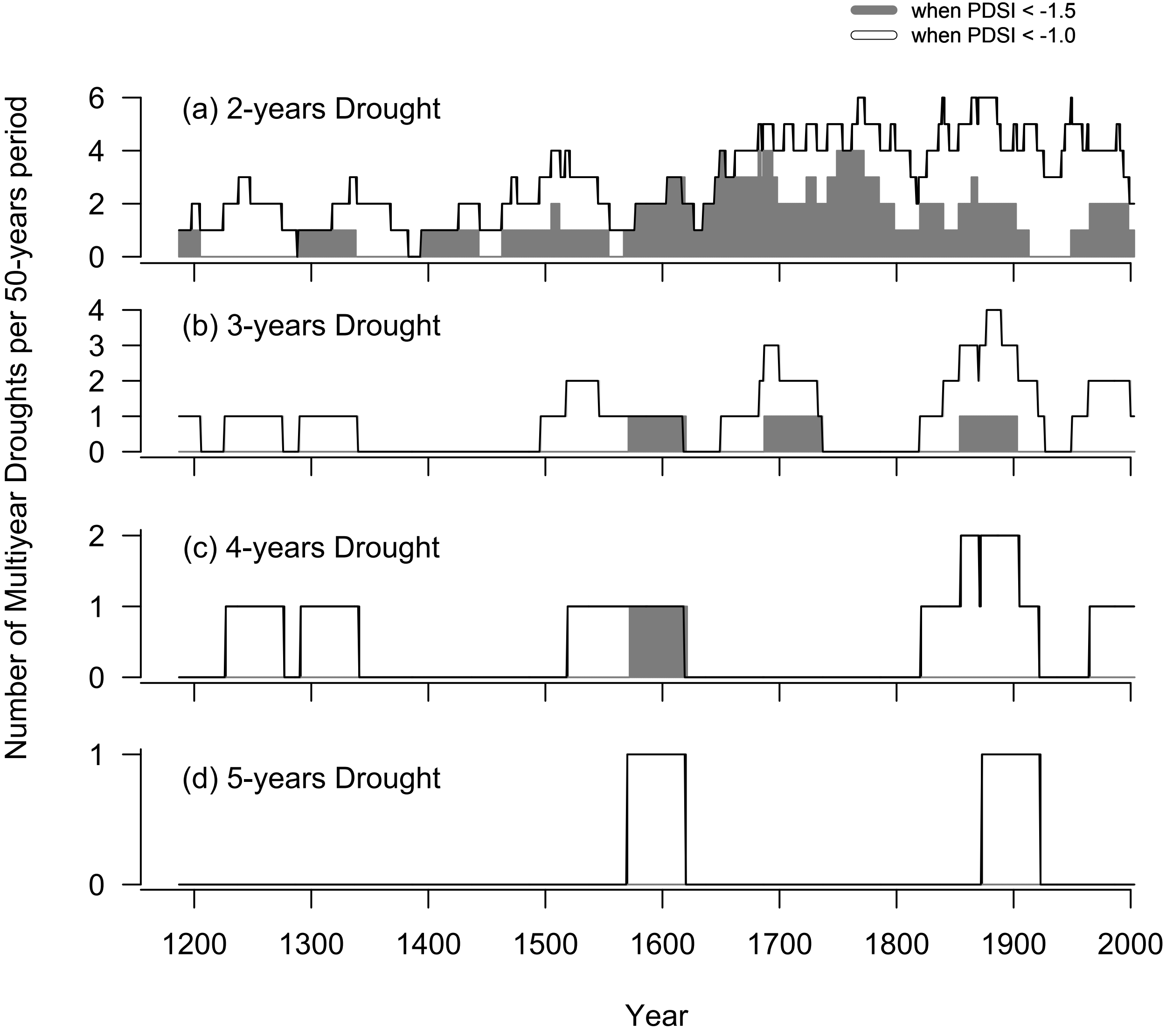

(a) 1401-1500
(b) 1601-1700
(c) 1801-1900
(d) 1901-2000
Correlation coefficients
1.0-0.8
0.8-0.6
0.6-0.4
0.4-0.2
-0.2--0.4
-0.4--0.6
-0.6--0.8
-0.8--1.0
Insufficient data

Figure 2



Dry (PDSI < −2)
Wet (PDSI > 2)
Number of dry years
Number of wet years
10
8
6
4
2
0
2
4
6
8
10
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
year

Figure 3



when PDSI < -1.5
when PDSI < -1.0
Number of Multiyear Droughts per 50-years period
(a) 2-years Drought
6
4
2
0
(b) 3-years Drought
4
3
2
1
0
(c) 4-years Drought
2
1
0
(d) 5-years Drought
1
0
1200
1300
1400
1500
1600
1700
1800
1900
2000
Year

Figure 4

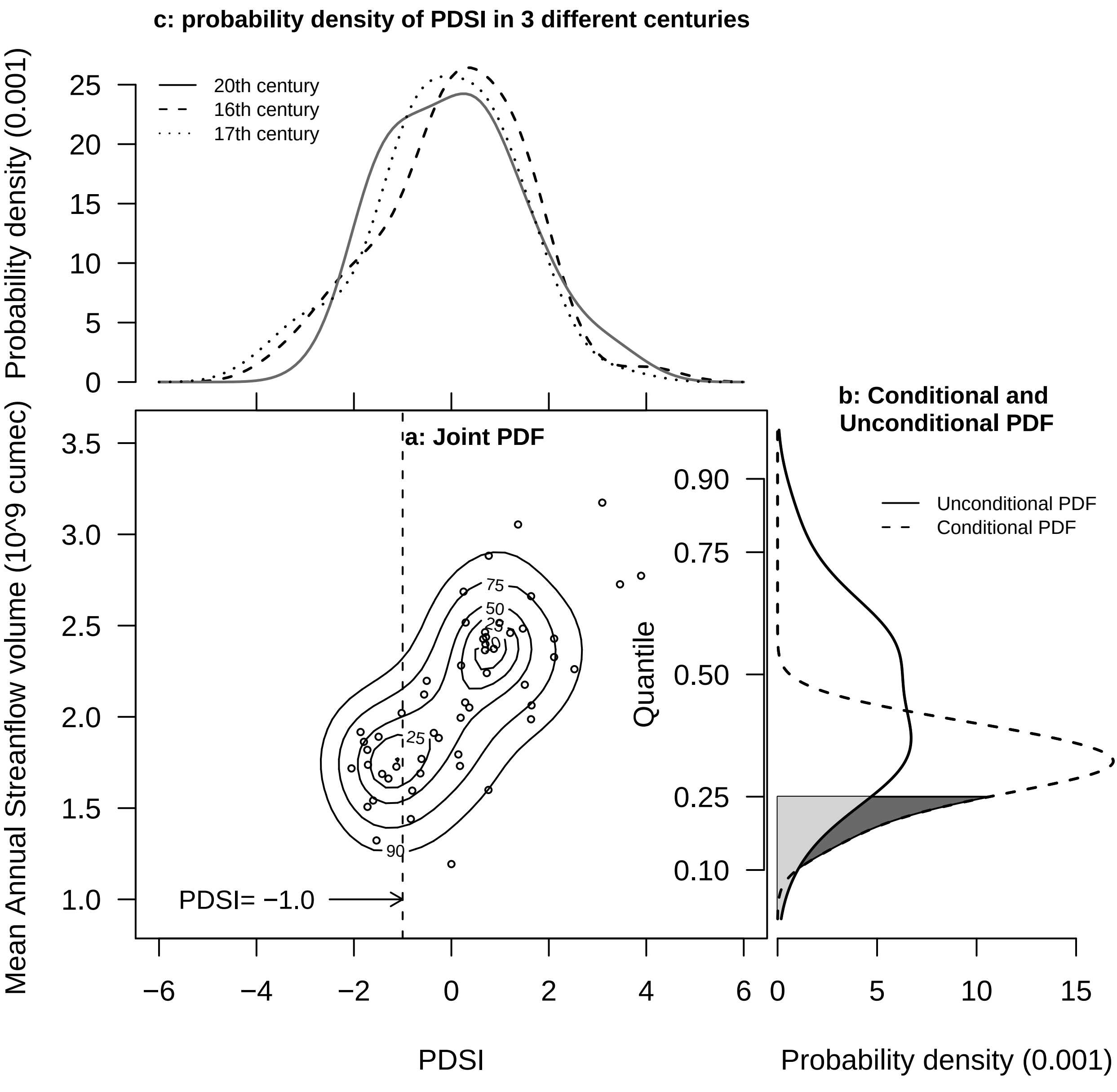
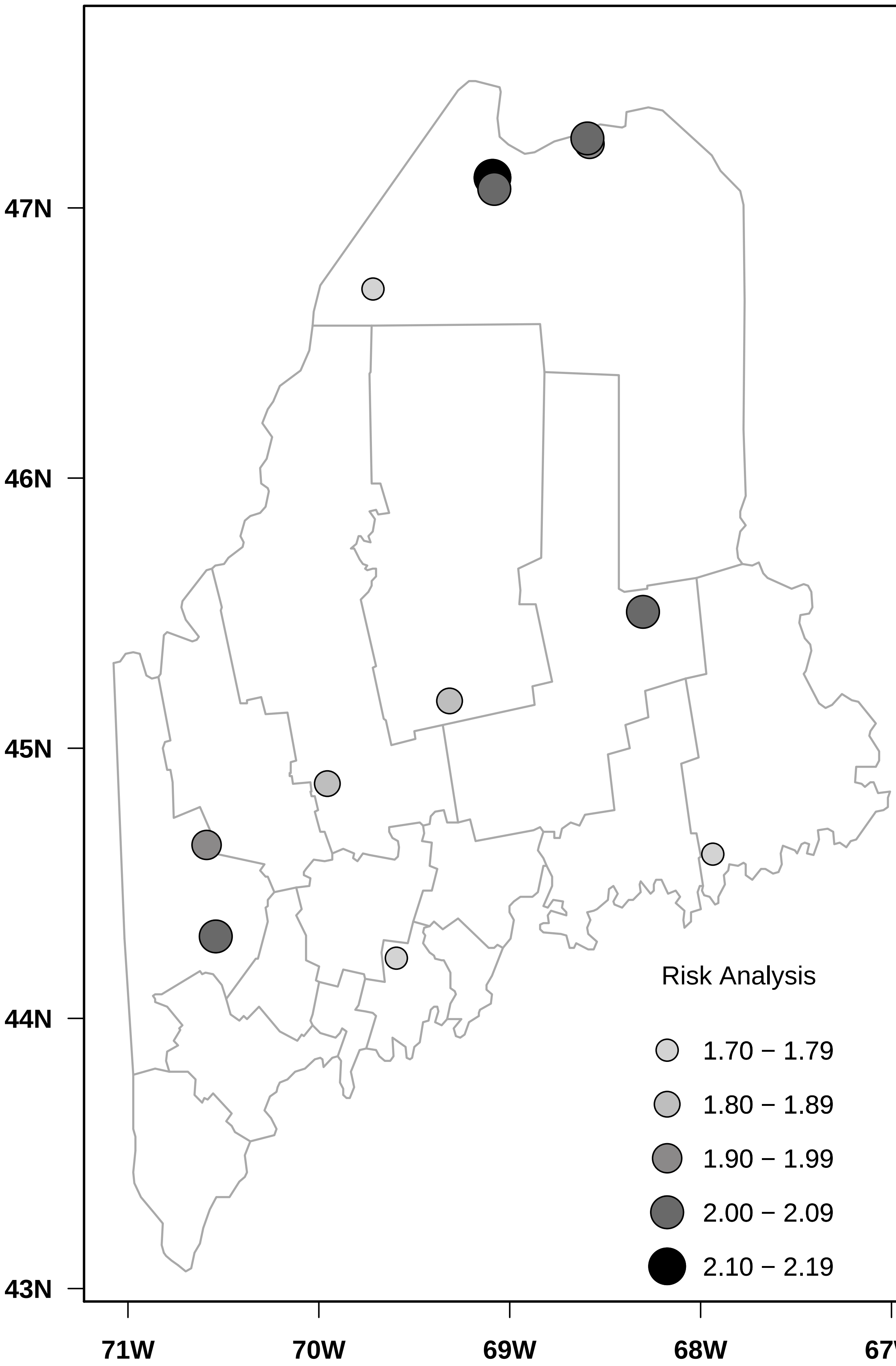

c: probability density of PDSI in 3 different centuries
Probability density (0.001)
25
20
15
10
5
0
20th century
16th century
17th century
a: Joint PDF
75
50
25
10
25
90
PDSI= −1.0
Mean Annual Streamflow volume (10^9 cumec)
3.5
3.0
2.5
2.0
1.5
1.0
−6
−4
−2
0
2
4
6
PDSI
b: Conditional and Unconditional PDF
Unconditional PDF
Conditional PDF
Quantile
0.90
0.75
0.50
0.25
0.10
0
5
10
15
Probability density (0.001)

Figure 5



47N
46N
45N
44N
43N
71W
70W
69W
68W
67W
Risk Analysis
1.70 − 1.79
1.80 − 1.89
1.90 − 1.99
2.00 − 2.09
2.10 − 2.19

Table

Table 1: General Characteristics of the selected USGS stream gauges in Maine

USGS Gauge Number	Gauge Name	Drainage Area (Sq. km)	Mean Daily Streamflow (m^3/sec)	Latitude (North)	Longitude (West)	Spearman Rank Correlation with PDSI
01010000	St. John River at Ninemile Bridge	3473.19	66.75	46°42'02"	69°42'56"	0.73
01010500	St. John River at Dickey	6941.2	134.93	47°06'47"	69°05'17"	0.71
01011000	Allagash River near Allagash	3828.02	55.10	47°04'11"	69°04'46"	0.66
01013500	Fish River near Fort Kent	2261.07	41.68	47°14'15"	68°34'58"	0.65
01014000	St. John River below Fish R, at Fort Kent	15317.26	275.69	47°15'29"	68°35'45"	0.69
01022500	Narraguagus River at Cherryfield	587.93	13.93	44°36'29"	67°56'07"	0.64
01030500	Mattawamkeag River near Mattawamkeag	3672.62	75.08	45°30'04"	68°18'21"	0.67
01031500	Piscataquis River near Dover-Foxcroft	771.82	17.72	45°10'30"	69°18'53"	0.67
01038000	Sheepscot River at North Whitefield	375.55	7.18	44°13'22"	69°35'38"	0.56
01047000	Carrabassett River near North Anson	914.27	21.41	44°52'09"	69°57'18"	0.60
01055000	Swift River near Roxbury	250.97	0.17	44°38'34"	70°35'20"	0.65
01057000	Little Androscoggin River near South Paris	190.37	3.92	44°18'14"	70°32'23"	0.61

Influences of dissolved organic carbon and iron on phosphorus photochemistry in surface waters

Basic Information

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Influences of dissolved organic carbon and iron photochemistry on phosphorus cycling in surface waters

Dustin Johnson – University of Maine

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Agency Funds Requested None

Problem and Research Objectives
The goal of this project is to investigate how dissolved organic carbon (DOC) influences the relationship between iron (Fe) and phosphorus (P) during exposure to ultraviolet radiation (UVR) in the UV-A range (315 – 400 nm). The focus of the project is to understand the chemical and physical changes that affect how P is cycled in surface waters that contain DOC and Fe. The objectives this research is designed to ascertain include:

- Quantify the effects of UV-A radiation (315 - 400 nm) on the fractionation of DOC-Fe-P and DOC-P complexes.
- Examine Fe fractionation that may occur in relation to any P sequestration or liberation during irradiation.
- Analyze the effects of UV-A radiation on DOC absorbance during and after irradiation.
- Determine the mechanisms and relationships involved with P sequestration or liberation from DOC and DOC-Fe complexes during irradiation.
- Quantify the size distribution of colloids formed during irradiation using ultrafiltration.

Materials and Methods
This project was designed to control the concentrations of all components in solution (e.g. DOC, Fe, P) and the properties of the solution (e.g. pH and temperature) to evaluate the relationships between DOC, Fe, and P during irradiation. All research was done in the laboratory using Suwannee River fulvic acid (SRFA) or water collected from a local bog in Old Town, Maine with a high concentration of fresh DOC.

Two varieties of solution are created in the lab to assess a well characterized organic matter (SRFA) and a natural, fresh organic matter. Solutions created using SRFA were made by adding known concentrations of SRFA to DI water in a 1 L volumetric flask wrapped in aluminum foil on a stir plate. The solution was stirred for 15 minutes before adding P as K_3PO_4. The solution continued to stir for 15 minutes before the addition of Fe as $FeCl_3$. The solution was allowed to homogenize for another 15 minutes before the pH was adjusted to 5.0 +/- 0.1 using a 0.1 M NaOH solution. After pH adjustment, the solution was continually stirred for 24 hours before removal and storage in the dark for 24 hours. Solutions created with bog derived organic matter were created in a similar process, diluting concentrated bog water (~35 ppm DOC) with DI water to the desired DOC concentration. Once mixed with DI water, P and Fe were added in the same process as with the SRFA solutions.

On the day of experimentation, 200 ml of DI water were added to the solution and the pH was adjusted to 5.5 +/- 0.1. Samples were taken at time zero (before irradiation) while the remaining solution was added to 6 quartz crystal flasks and placed in a Rayonet Photochemical Chamber Reactor to undergo irradiation. Samples were taken every 15 minutes for the first hour and every 30 minutes for the second hour. Each set of samples was subject to a series of physical manipulations to determine the concentrations of DOC, total Fe/P, organically bound Fe, <0.45 μm Fe/P, <100,000 Daltons (Da) Fe/P, and <5,000 Da Fe/P (**Figure 1**). DOC was measured using a 1010 WIN TOC carbon analyzer. Fe was measured using flame atomic absorption spectroscopy. P was measured colorimetrically using a Varian Cary 100 spectophotometer.

Principal Findings and Significance

Preliminary Experiments

Preliminary experiments yielded no definitive answers as to how DOC and Fe influence P during exposure to UVR. These experiments showed that the DOC concentration decreased between 7-13% during irradiation, which is consistent with previous DOC-UV experiments (Porcal et al., *in prep*). This indicates that photochemical reactions are taking place and a small percent of DOC goes to CO_2 during irradiation. The concentration of Fe particulates greater than 0.45 μm remained consistently less than 1.0 μM Fe; this accounts for 10-14% of the total Fe in solution. Based on our hypothesis, the lack of particulate Fe that forms during irradiation is not significant enough to adsorb and remove P from the water column. The P data confirmed this hypothesis as >90% of the P was less than 0.45 μm and showed no correlation with the particulate Fe data. The preliminary data indicated that Fe and P greater than 0.45 μm had no correlation and that irradiation was not causing Fe particulates greater than 0.45 μm to form.

Ultrafiltration Experiments

Based on the evaluation of the preliminary data series, we inferred that particulates of both Fe and P may be forming at size fractions less than 0.45 μm . To test this hypothesis we passed samples through 100,000 and 5,000 Da ultrafilters to evaluate the creation of colloidal Fe during irradiation (**Figure 1**). We have established a relationship between Fe and P at three progressively smaller size fractions; 0.45 μm, 100,000 Da (~50 nm), and 5,000 Da (~3 nm). Current data indicates that P does associate with Fe colloids that form at less than 0.45 μm to 100,000 Da and 100,000 Da to 5,000 Da in size.

We are currently investigating the role of DOC concentration in determining the colloid size fractions that form. We have shown that low DOC concentrations allow for larger colloids to form (**Figure 3**), while higher DOC concentrations retard colloidal particulate growth (**Figure 2**). Without the use of ultrafiltration it is not possible to see any association between Fe and P despite the relationships between Fe and P at smaller size fractions. This has large implications for how we currently defined “dissolved” in aquatic chemistry.

Future Work

Future work on this project will focus on the development of a relationship between DOC concentration and colloid size formation. It is important for us to understand what varying concentrations of DOC does to environments where Fe and P are cycling photochemically. The goal for the remainder of this project is to define how the concentration of DOC influences and determines Fe and P colloid size and interaction.

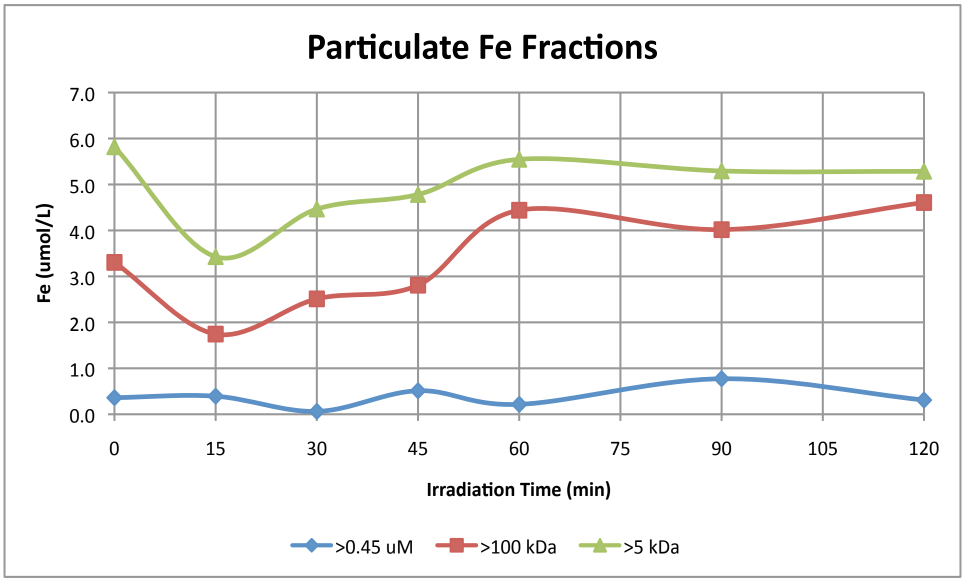

Figure 2. Particulate Fe size fractions during 120 minutes exposure to UV-A radiation with 5.5 ppm (0.45 mM DOC). Increased DOC concentration leads to the dominance of smaller sized colloid formation during irradiation.

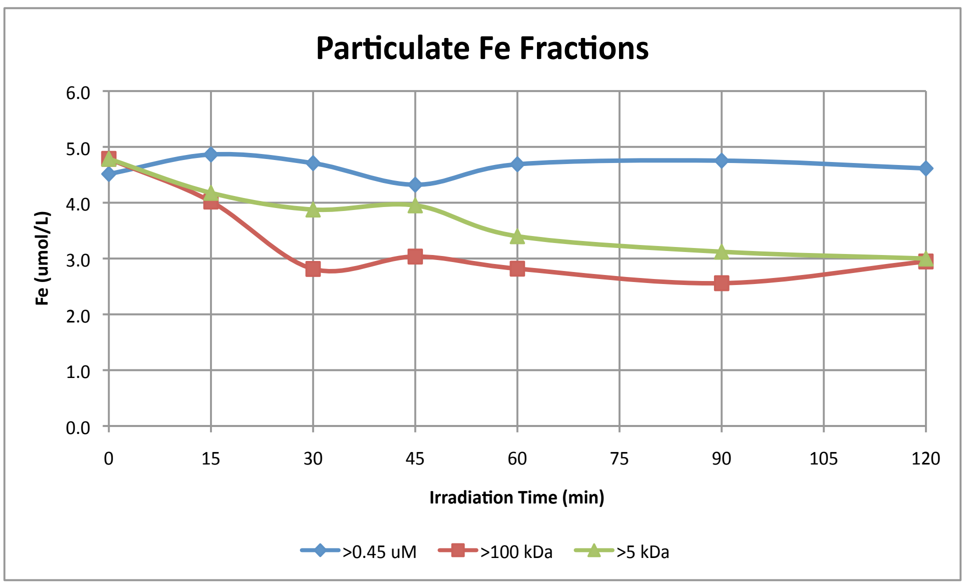

Figure 3. Particulate Fe size fractions during 120 minutes exposure to UV-A radiation with 0.3 ppm (0.024 mM) DOC. Low concentrations of DOC nominally inhibit particulate formation and lead to larger sized colloids.

Temporal changes of the phosphorus concentration profiles in two Maine lake sediment porewaters using a passive sampling technique.

Basic Information

Title:	Temporal changes of the phosphorus concentration profiles in two Maine lake sediment porewaters using a passive sampling technique.
Project Number:	2009ME190B
Start Date:	3/1/2009
End Date:	2/29/2010
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Geochemical Processes, Hydrogeochemistry, Methods
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publications

1. Lake B, Norton S, and Amirbahman A. Seasonal changes in sediment porewater chemical gradients in two Maine Lakes: A diffusive equilibrium study. (in preparation)
2. Lake, B. 2009, Biogeochemical phosphorus cycling in the sediments of shallow temperate lakes, Ph.D. Dissertation, Department of Civil and Environmental Engineering, College of Engineering, University of Maine, Orono, ME, pp. 206.

Title: Temporal changes of the phosphorus concentration profiles in two Maine lake sediment porewaters using a passive sampling technique.

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A. Research Program

Problem and Research Objectives

Phosphorus (P) is often the limiting macronutrient in freshwater ecosystems. Eutrophication is a problem affecting many Maine lakes, especially in the Belgrade Lakes region. Bjorn focused his dissertation on P cycling between the sediment and water column of Salmon and Lovejoy ponds. He used a passive sampling technique involving hydrogels to measure the P porewater concentration gradients in both ponds. Each pond develops large P concentration gradients in the hypolimnion during the summer stratification period. Preceding the release of P from the sediment to the water column, Bjorn's hypothesis was the P porewater concentration depth profiles change dramatically and characteristically in each pond based on sediment properties. He measured the porewater in both ponds at four times during the winter, spring and summer. Based on his literature search, this was the first time P porewater profiles will be examined temporally using hydrogel technology. This research augmented his knowledge of these systems and provided the data needed to complete the final chapter of his dissertation.

Both Salmon and Lovejoy ponds experience mild to severe algal blooms during the summer months which correspond with large vertical concentration gradients of P in the hypolimnion. This suggests that P is being released from the sediment and contributes to the productivity of each lake. Sediment chemical extractions of both ponds have been analyzed by standard methods and nuclear magnetic resonance. These data have shown that indeed the sediment is a major source of P to the water column. However, the mass balance of solid phase P released in the sediment to the P accumulated in the water column has not matched, though the trends are convincing. In Salmon Pond, the amount of P released from the sediment solid phase is much larger than the accumulated P in the hypolimnion and, in Lovejoy Pond, the amount of P accumulated in the hypolimnion is much larger than the P released from the sediment solid phase. To explain these mass balance discrepancies, accurate P porewater concentration profiles are needed to model the flux of P upward into the water column and downward into the sediment from the concentration maxima.

Objectives:

- Accurately measure the concentrations of P and metals in the porewater of Salmon and Lovejoy pond in the winter, spring and summer.
- Use the collected data to model the flux of P at different times during the year.
- Compare the results to already published values.
- Suggest possible mechanisms of P release using the porewater results and possible remediation strategies for mesotrophic to eutrophic ponds.

Methodology

The methods of this project were thoroughly scrutinized and tested. A benthic lander was built to accommodate the sampler paddles. Each lander was equipped with 4 paddles for each deployment, two with a cell spacing of 1.5 cm and two with a cell spacing of 0.75 cm. One paddle was used to measure the pH of the porewater, 2 paddles for P analysis, and the remaining paddle for metals. The benthic lander was deployed in the profundal zone of the lake for 2 full days to reach equilibrium with the sediment porewater. Upon retrieval, an Aquavision underwater viewer was utilized to inspect the positioning of the benthic lander in the sediment. Immediately after retrieval, the pH paddle was analyzed at the site with a portable pH probe to minimize carbon dioxide degassing. Hydrogen activity will be used to calculate metal and P speciation and solubility. The remaining paddles were returned to the lab, disassembled, and the gels placed in 25 mL of 0.25M sulfuric acid for P analysis and 10 mL of 0.1M nitric acid for metals analysis. P analysis was done using standard colorimetric methods and the metals were analyzed with an inductively-coupled plasma optical emission spectrophotometer (ICP-OES).

Principal Findings and Significance

The results show that for both lakes, Fe and P exhibit similar patterns in the sediment. In the early part of the year, deeper sediments have zones of production which supply the upper sediment with P and Fe. By the time the oxycline reaches the sediment-water interface (SWI), a large reservoir of reducible P and Fe has accumulated. When the hypolimnion becomes anoxic, initially there is a large flux value of both Fe and P which steadily declines as the summer stratification period progresses due to the depletion of the solid phase and a lessening of the chemical gradient caused by hypolimnetic accumulation. Throughout the year, zones of Fe and P production also create chemical gradients that diffuse into the deeper sediments replenishing the solid phases at depth. Vivanite and hydroxyapatite are supersaturated in the zones of consumption at depth suggesting these mineral formations are possible sinks of Fe and P. The main difference between the P production zones of the two lakes are the size and the proximity to the SWI. Also, the eutrophic lake has more evidence of microbial uptake of sedimentary P and a higher degree of rapid mineralization later in the year at the SWI.

B. Information Transfer Program

The results of this research work have been and will be disseminated via three methods. First, the research was the final chapter in Bjorn's dissertation. The dissertation will be available through the University of Maine's Graduate School, Department of Environmental and Civil Engineering, and Fogler Library. Second, the completed research will be part two in a companion paper series submitted to a peer-reviewed publication with part one consisting of previously conducted research on Lovejoy Pond and Salmon Lake. Currently, the manuscript is in preparation with expected submission at the end of February, 2010. Finally, the results from this research will be presented as oral presentations. The first instance was Bjorn's dissertation defense that was completed and passed on December 4, 2009. On February 3, 2010, Bjorn will present his findings to the Maine Department of Environmental Protection as part of their monthly staff meeting. On March 17, 2020, the research will be presented at the Maine Water Conference to water resource professionals, agency staff, and interested stakeholders. Other presentations that have not been scheduled yet are professional conferences and job interviews.

C. Other required documentation

Student support

The budget for this project consists of three months stipend for Bjorn Lake ($3,250). The matching funds consisted of the analysis paid to the Environmental Chemistry Lab at the University of Maine with pre-existing, now expired, NSF funds ($4,500).

Publications

1. Articles in Refereed Scientific Journals

Lake B, Norton S, and Amirbahman A. Seasonal changes in sediment porewater chemical gradients in two Maine Lakes: A diffusive equilibrium study. (in preparation)

2. Dissertation

Lake, B. 2009, Biogeochemical phosphorus cycling in the sediments of shallow temperate lakes, Ph.D. Dissertation, Department of Civil and Environmental Engineering, College of Engineering, University of Maine, Orono, ME, pp. 206.

Impacts of White Perch Introductions on Trophic Dynamics: Paleolimnological Record of Zooplankton Grazing and Nutrient Cycling

Basic Information

Title:	Impacts of White Perch Introductions on Trophic Dynamics: Paleolimnological Record of Zooplankton Grazing and Nutrient Cycling
Project Number:	2009ME193B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	2
Research Category:	Biological Sciences
Focus Category:	Ecology, Management and Planning, Water Quality
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publications

There are no publications.

Impacts of White Perch Introductions on Trophic Dynamics: Paleolimnological Record of Zooplankton Grazing and Nutrient Cycling

Focus categories: Ecology ECL, Management and Planning M&P, Water Quality WQL

Keywords: Algae, Ecosystems, Eutrophication, Fish Ecology, Lakes, Nutrients, Ponds, Water Quality, Water Quality Management, Zooplankton

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Project Date and Duration: May 1, 2009 until October 31, 2009

Agency Funds Received: $4,497

Problem and Research Objectives:

Fish introduction to lake ecosystems produces long-lived changes in zooplankton and algal communities via cascading interactions in food webs (Leavitt, 1989). Trophic cascades occur when impacts from the upper levels of the food web cause corresponding changes in lower levels. Cascading influences of fish typically result from strong predation by planktivorous fish on zooplankton, resulting in reduced grazing pressure on algae (Brooks and Dodson, 1965). In some cases, these cascading effects can lead to substantial increases in algal abundance, or algal blooms, which cause aesthetic and water quality problems for lake users as well as degrading ecosystem health (Jeppesen, 1990). The mechanisms underlying these trophic cascades are complex and many factors can alter the response of food webs to manipulation. For example, besides direct trophic interactions, introduced fish can affect lower trophic levels through alterations in the cycling of nitrogen and phosphorus (Vanni, 1997). As a result, untangling the interactions between fish introductions and water quality is difficult.

This type of cascading influence of an introduced fish is thought to have contributed to the reduced water quality in East Pond, Maine. Between approximately 1920 and 1950, white perch, a planktivorous fish, was introduced to East Pond, a shallow, mesotrophic lake located in the Belgrade Chain of Lakes in central Maine. Since this time there has been an increase in the frequency of noxious algal blooms and a decrease in water clarity. To address this, the Maine Department of Environmental Protection has implemented a lake biomanipulation project in which white perch are being removed from the lake. The removal of an abundant planktivorous fish from the food web can reduce predation by fish on the zooplankton community, which is predicted to favor large bodied zooplankton that have an increased grazing efficiency on algae. An increase in algal consumption can reduce biomass and reduce the potential for noxious algal blooms. This is known as a top-down control on water quality dynamics.

However, preliminary results from the biomanipulation on East Pond suggest responses by the plankton community that are counter to those expected from changes to top-down predation effects. Direct influences on lake water quality such as nutrients (total phosphorus) and zooplankton grazing pressure (cladoceran biomass) were monitored in East and North Ponds prior to fish removal in 2004 to 2006, and after fish removal in 2007, 2008 and 2009. In the three years of white perch removal, cladoceran body size declined (counter to predictions) in late summer. Algal blooms were less severe in the two years of perch removal, but not lower than all years monitored prior to fish removal. Interpretation of these results is difficult due to limitations in the amount of data used to quantify pre and post conditions as well as the lack of replication due to the scale of the experiment.

Paleolimnological techniques, using lake sediment records to study long term changes to the lake ecosystem, are used to analyze the long-term, complex interactions that occur in lakes due to alterations in fish community. For example, an analysis of the sediment record of East Pond revealed that after 1950 (approximate timing of perch introduction) the zooplankton community showed an increase in body size with an increase in the size divergence (counter to predicted top-down predation effects). Additional paleolimnological studies can provide information about fish effects on trophic dynamics in respect to long-term developments, past conditions, and biological response at the whole lake scale.

The historical patterns of algal and zooplankton communities, as recorded in lake sediments, were used to study the long-term effects of white perch introduction to Maine lakes. In lakes with known dates of white perch introduction and others without perch introductions, sedimentary records were analyzed for changes in fossil pigments (indicator for shifts in the algal community) and zooplankton (indicator for shifts in cladoceran size structure and species composition). In addition to community changes, possible shifts in water clarity were also examined. Thus, the objective of this study is to analyze the long-term impacts, past conditions, and biological response of planktivorous fish introduction on Maine lakes. These results will be compared to the whole-lake biomanipulation project on East Pond in order to gain a better understanding of the complex mechanisms by which fish introductions affect plankton dynamics and to assess the applicability of biomanipulation as a management approach for improving water quality.

Analyzing ecosystem communities before and after food web manipulation on the scale of hundreds of years will provide the larger perspective needed in understanding fish effects on trophic dynamics. The comparison of records from multiple lakes will provide insight into fish introduction across broad spatial scales. Management of water quality requires a better understanding of the large-scale and long-term impacts of planktivorous fish introduction. Results from this study will guide management decisions aimed at treating water quality through food web manipulation.

<u>Objectives:</u>

- Use paleolimnology to assess impacts of white perch introduction on:
    - Zooplankton community structure
    - Algal community composition
- Compare these results to the East Pond biomanipulation project and assess the applicability of biomanipulation as a treatment for improving water quality.

Methods:

In June 2009, sediment cores were taken from the deepest part of 4 lakes (Ell Pond, Keoka Pond, Forest Lake, and Swan Pond), each of which has a documented date of white perch introduction. The lakes are close in proximity to isolate for climatic variables and similar in morphometry, watershed characteristics, and nutrient concentrations. The introduction dates span the past century: Ell Pond introduction occurred in 1913 and extirpation occurred in 1958 after the pond was chemically reclaimed; Forest Lake introduction occurred in 1964; Swan Pond introduction occurred in 1960; and Keoka Pond introduction occurred in 1996 with no changes in fish community during the time of introduction in the other ponds to serve as a control for identifying regional drivers. The lakes were chosen in consultation with the Maine Department of Environmental Protection and Maine Inland Fish and Wildlife.

Sediments were collected by boat with a modified K-B gravity corer (Glew, 1989). The top 20 cm of each core were sectioned into 0.5 cm increments in the field. The cores were dated using ^{210}Pb constant rate of supply model (Oldfield and Appleby, 1978) in the Physics Department at the University of Maine. Sediments were counted for 24 hours by gamma ray spectrometry until baseline ^{210}Pb activity was reached.

From each sediment core, approximately twelve successive 0.5 cm sections spanning before, during and after fish introduction were analyzed for fossil pigments and cladoceran ephippia.

Fossil pigment analysis was based on standard high performance liquid chromatographic separations of chlorophylls (chls), carotenoids and their derivatives (Leavitt and Findlay 1994), including pigments from all algae and plants (3 carotene, chl a, pheo- phytin a), chlorophytes (chl b, pheophytin b, lutein), total cyanobacteria (echinenone, zeaxanthin), colonial cyanobacteria (myxoxanthophyll, canthaxanthin), N2- fixing colonial cyanobacteria (aphanizophyll), siliceous algae and some dinoflagellates (fucoxanthin), diatoms (diatoxanthin), and cryptophytes (alloxanthin).

Principal Findings and Significance:

With the help of the USGS WRRI grant program, four cores were collected and sedimentary fossil pigment analysis was completed. The fossil pigment analyses were used to shed light on the changes in past primary production and because many pigments show a degree of taxonomic specificity, they provide information about the past algal community during changes in the food web (McGowan, 2007).

All study ponds showed a decreasing trend in algal pigments including canthaxanthin (cyanobacteria), zeoxanthin (cyanobacteria), lutein (green algae, euglenophytes), diatoxanthin (diatoms, dinoflagellates, chrysophytes), and alloxanthin (cryptophytes) occurring at the time of fish introduction to present. Pigments in Ell Pond showed a subsequent increase in pigments after the date of white perch extirpation to present. During the time in which white perch were present in Ell Pond, compounds that absorb in the ultra violet (UV) region were detected. These compounds are produced primarily by cyanobacteria in lake sediments and may function as photoprotectants because they are produced in response to UV exposure (McGowan, 2007). The presence of this pigment when all other pigments are declining indicates an increase in lake transparency (Leavitt et al, 1997). UV absorbing pigment was also detected in Forest Pond at the time of introduction, when all other pigments were decreasing. Although no UV pigment was detected, Swan Pond also showed a decreasing trend in pigments at the time of introduction. Over the same time period in which the other lakes were showing a decreasing trend in fossil pigments, Keoka Pond (with an introduction date of 1996) showed the opposite trend. Pigments in Keoka Pond show a steady increase from 1950 until the present, with several pigments showing a decline in the surface sediments (the time at which white perch were introduced).

Analyses of all four study lakes show a decrease in algal pigments at the time of white perch introduction, and in some ponds an increase in water clarity. The comparison of ponds to Keoka Pond suggests that the results seen at the time of white perch introduction are not the result of a regional driver such as changes in climate. Analysis of the zooplankton community before, during and after introduction show variable results, in Forest Pond ephippia size increases after introduction (similar to results observed in East Pond) while in Ell Pond there is no change in ephippia size at introduction or removal. These results are counter to those expected from a "top-down" trophic cascade caused by planktivorous fish introduction. Although the results are not what one would expect from planktivorous fish introduction, the pigment results suggest that fish introduction is having a marked impact on the algal community and water clarity. This suggests that rather than nutrients, changes in food web structure may be the dominant control on algal communities in some Maine lakes. This analysis provides the long-term and broad scale perspective needed in understanding fish effects on trophic dynamics. Further analysis of the diatom community will provide insight into changes in nutrients over that time period, and changes in the landscape will be investigated by analyzing changes in the organic content of the soil.

Using GC/FT-ICR MS for the Identification of Disinfection By-products

Basic Information

Title:	Using GC/FT-ICR MS for the Identification of Disinfection By-products
Project Number:	2009ME194B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Toxic Substances, Methods, Water Quality
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publications

There are no publications.

Methodology: Gas Chromatography / Flame Ionization Detection

1.1 Scope

In the following report, we show the advantages of combined use of gas chromatography-flame ionization detection and gas chromatography / Fourier transform – ion cyclotron resonance mass spectroscopy for quantitative detection of disinfection byproducts and halogenated compounds. This combination should allow accurate and precise measurements of DBP both in x (measured masses) and y (relative ion abundance) dimensions of a conventional mass spectrometry experiment. The FID provides improved and reproducible results in the y scale (relative abundance) and FT-ICR provides ultra high mass measurement accuracy. Improvements in these two dimensions will have impact beyond analysis of DBPs and is crucial for enhancing various "x-omics" studies such as metabolomics. In our particular case, the new combination can be applied to determine the abundance of disinfection byproducts that are present in water samples. Furthermore, we compare this method to that of electrospray ionization mass spectrometry to determine which method has the greater sensitivity for these compounds.

1.2 Introduction

Analytical chemistry is a growing field in all areas of the scientific world. Modern analytical methods contribute to the successes achieved in present day research areas. Numerous analytical methods are employed in the area of environmental chemistry. Research on the analytical methods used in this area will improve the confidence in instrumental measurements. Characteristics of instrumental analysis such as detection limits, sensitivity, and selectivity must always be improved as they are becoming ever more important in research.

Improving the detection limits, sensitivity, and selectivity is crucial to the advancement of the research on disinfection byproducts (DBPs). The United States Environmental Protection Agency (EPA) regulates known disinfection byproducts in drinking water. However, there are newly emerging disinfection byproducts that need to be identified. Improving the instrumental analysis can lead to more confidence in the identification and quantification of disinfection byproducts.

The reaction of disinfectants (such as chlorine, chloramine, ozone, chlorine dioxide, etc) with natural organic matter and/or bromine in the source water form disinfection byproducts in drinking water. (1) Regulations have been established for the following disinfection byproducts: trihalomethanes with a maximum annual average of 80 ppb, haloacetic acids with a maximum annual average of 60 ppb, chlorite with an annual average of 10 ppb, and bromate with a monthly average of 1 ppm. It is estimated that 50% of the total organic halide (TOX) in chlorinated drinking water remains unidentified, although hundreds of DBPs have been identified. (2)

Multiple methods are being employed to identify and monitor DBPs in drinking water. Brown et al. reports on a method for near real-time analysis for monitoring trihalomethanes in water distribution systems. (5) Automated online purge and trap GC with a dry electrolytic conductivity detector was the instrument used in this investigation. The method was applied to chlorinated and chloraminated distribution systems. A silicone capillary membrane is in place allowing drinking water to flow through while pervaporating the trihalomethanes. The trihalomethanes are then preconcentrated with an adsorbent trap and analyzed with GC / conductivity.

Liquid chromatography is being coupled with electrospray ionization mass spectrometry (ESI-MS) to determine new DBPs. Ding reports using ultra-performance liquid chromatography (UPLC) with ESI-MS to investigate polar iodinated DBPs. (3) From this research seventeen new iodinated DBPs were proposed. Zhang et al. detected and identified unknown brominated DBPs with negative ion ESI – triple quad mass spectrometry. (4) Precursor ion scans of m/z 79 and 81 were employed in this experiment. Zhang reports finding many polar brominated DBPs using this method.

In 2007, Devlin et al. reported using membrane introduction coupled with flame ionization (FID) and electron capture detectors (ECD). (6) Reduced organic compounds can be distinguished from oxidized organic compounds using the relative intensities obtained from the FID and ECD. Devlin concluded that MIFID/ECD can be used as a real-time screening application allowing for rapid discrimination of contaminant classes.

With this research, we want to employ GC-FID to allow accurate quantitative data along with FT-ICR/MS for confident identification of DBPs. It has been previously reported that although FT-ICR offers unequaled mass measurement accuracy and resolving power, it does not provide accurate relative abundances. (7) Using GC-FID with FT-ICR MS we hope to identify new DBPs as well as obtaining quantitative data for their relative abundances.

1.3 GC/FID Setup and Sample Injections

Headspace volumes were injected onto a Restek MXT-1 (Bellefonte, PA, USA) (60-m × 0.28 mm i.d. × 3.0 µm film thickness, 100% dimethyl polysiloxane stationary phase coating) capillary column housed in an SRI model 8610C GC oven (Las Vegas, NV) for separation. The GC temperature programming utilized for acquiring GC-FID data started at an initial temperature of 50°C and was held constant for 5 minutes after which it was ramped at 5°C per minute to a final temperature of 120°C and held constant for 16 minutes. The total run time was thirty five minutes.

Injections were done from a mixture of known disinfection byproducts. The mixture consisted of chloroform, chlorodibromomethane, and dichloroacetonitrile. Samples were prepared in a 40 mL EPA septum sealed vial. A gas tight syringe was used to inject headspace from the sample vial into the GC. Peak simple software was used to acquire the data.

1.4 Results and Discussion

Initial experiments were conducted using the GC/FID to determine relative response factors of the compounds to acetone in order to help provide quantitative data for DBP analysis. The following relative response factors were calculated: chloroform – 0.8763, dichloroacetonitrile – 0.6063, and chlorodibromomethane – 0.5240.

Sample was introduced to the GC-FID with varying injection amounts. Sample was able to be detected at amounts as low as 100 picomoles. Data was compiled into the following plot:

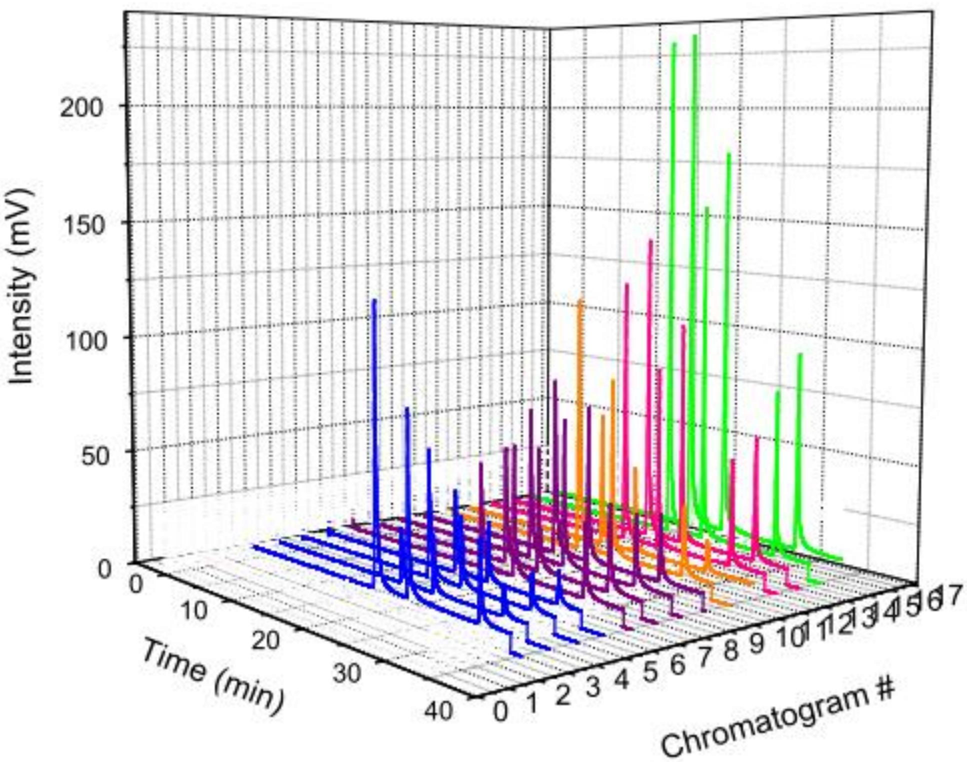

Figure 1: Data plot showing relative intensities and retention times of sample mixtures. Each mixture contained chloroform, dichloroacetonitrile, and chlorodibromomethane. Injection amounts range from 100 picomoles to 61.2 nanomoles. Multiple injections of the same amount are represented by the same color.

Retention times for the halogenated compounds are as follows: chloroform – 18.2 minutes, dichloroacetonitrile – 22.6 minutes, and chlorodibromomethane – 31 minutes. The compiled data show increasing signal intensity with increasing injection amounts. This data will be used to calculate detection limits and sensitivity.

1.5 Future Work

This project will be continued into the spring semester. FID data will be further analyzed. Mass spectral data needs to be collected using both GC/FT-ICR MS and ESI MS. The two methods will be compared in order to determine which has the greater sensitivity for the DBPs and halogenated compounds.

References:

1. U.S. Environmental Protection Agency, 2009, **Disinfection Byproducts: A Reference Resource**, http://www.epa.gov/enviro/html/icr/gloss_dbp.html

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Information Transfer Program Introduction

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The Maine Water Research Institute links the academic community with state agencies, environmental organizations, private companies, and the citizens of the State of Maine. The water resources of the state are extremely important for ecosystem service, recreation (tourism), fisheries, and industry. The Water Research Institute serves the State of Maine as a point of access to the substantial technical abilities of the University of Maine System on issues relevant to water resources. The Institute also is relied upon for timely and accurate information transfer activities that is augmented by additional non-federal funding. We work closely with the Mitchell Center to link knowledge to action and to support projects that include strong stakeholder involvement. The Sustainability Solutions Initiative now provides even greater connections with all of the institutions of higher learning in the state. In this effort the Water Research Institute has worked to disseminate research results through various media, organized meetings and conferences, participated in statewide forums, served on committees dealing with water resource issues, worked with teachers to bring water science into the classroom, and provided opportunities to build new partnerships.

Regional Pilot to Reduce Stormwater Polluting Behaviors through Social Marketing as an Environmental Education Tool in the Bangor Urbanized Area

Basic Information

Title:	Regional Pilot to Reduce Stormwater Polluting Behaviors through Social Marketing as an Environmental Education Tool in the Bangor Urbanized Area
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Principal Investigators:	Scott Wilkerson, Laura R Wilson

Publications

There are no publications.

Changing Bangor Area Lawn Care Behavior

Results from the Evaluation Survey

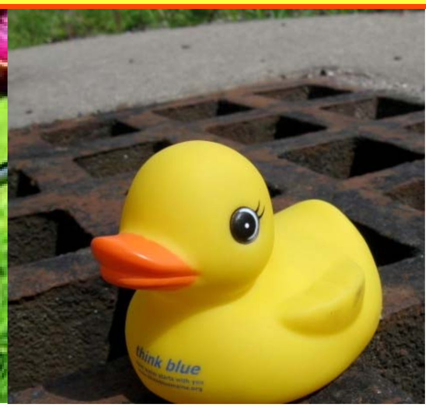

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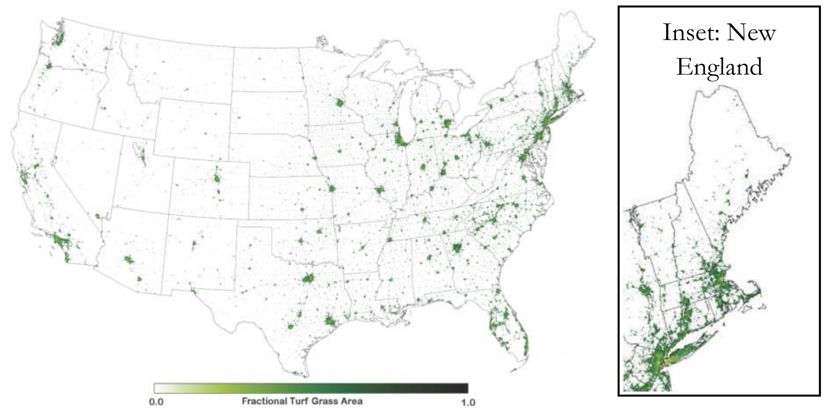
Table of Contents

1. Introduction

1.1. Lawns, Nonpoint Source Pollution, and the Environment

Since its original colonization in the late eighteenth century (Jenkins 1994) the turfgrass lawn has grown to dominate yards, parks, athletic fields, golf course, waysides, and just about every open space managed by Americans, blanketing an estimated 32 million acres across the country (Milesi et al. 2005). According to a study by Robbins & Birkenholtz (2003), lawns in the United States inhabit approximately 23% of all developed land and have become the dominant land cover type for urban areas. Figure 1 shows a national map depicting the percent turfgrass for the contiguous United State, including an inset of New England (map provided by Milesi et al. 2005). Furthermore, the American lawn receives more care, time, and attention from individuals and households than any other natural space (Robbins 2007). Americans spend an estimated 40 billion dollars a year on lawn care, which is more than the Gross National Product of Vietnam (Steinberg 2006). A major driver of this expansion and obsession with lawns is the socio-cultural importance of lawns in the United States that had developed over the past sixty years (Jenkins 1994; Steinberg 2006; Robbins 2007).

Figure 1: Percent Turf Grass across the US



The affects of lawns and lawn care behavior contribute to a variety of negative impacts on the environment, including degrading water quality through the use of lawn chemicals (such as fertilizers and pesticides), diminishing air quality through lawn mower exhaust, and increasing water consumption for watering (Bormann et al. 2001). An issue of particular importance concerns fertilizer and pesticide runoff from lawns, which is a significant contributor to nonpoint source pollution (NPS). Fertilizer runoff has been associated with algal blooms, eutrophication, and contaminated groundwater and pesticides can be very toxic to humans and copious non-human species. In fact, the United States Environmental Protection Agency (EPA) states that nonpoint source pollution is the Nation's leading source of water quality degradation (EPA's "Managing Nonpoint Source Pollution from Households" 2009).

The harmful lawn chemicals, which are found in increasing abundance in the nation's surface and ground waterways, remain largely unregulated despite congressional appeals and testimony (Guerrero 1990). It is also noteworthy to mention that NPS problems caused by fertilizer and pesticide use have yet to be adequately addressed some 30 years after the passage of the Clean Water Act (Adler et al. 1993). This is testament to the difficulty in managing NPS pollution not only due to its diffuse source, literally millions of lawns across the country, but also because it works against the cultural auspices of maintaining the traditional lawn.

The harmful lawn chemicals which are found in increasing abundance in the nation's surface and ground waterways remain largely unregulated despite congressional appeals and testimony.

There are a range of organizations interested in influencing lawn care practices, such as University extension, watershed councils, and state and federal agencies. In most cases, these organizations are encouraging voluntary behavioral changes aimed to reduce environmental impacts, such as leaving clippings on the lawn, eliminating the use of lawn chemicals, and mowing less often. These non-regulatory approaches used to address this issue seem the best, and perhaps only, method given the challenges present for addressing NPS pollution. However, there has been very little research that either investigates lawn care behavior or evaluates the effectiveness of programs used to promote environmentally responsible lawn care behavior (Robbins et al. 2001).

1.2. Changing New England Lawn Care Behavior Project

To help address the issue of NPS pollution from lawns in New England the research project titled *Changing Homeowner's Lawn Care Behavior to Reduce Nutrient Losses in New England's Urbanizing Watersheds* was developed (USDA CSREES (now NIFA) project # 2006-51130-03656). This project was funded by the United State Department of Agriculture's (USDA) Cooperative State Research, Education, and Extension Service (CSREES), which recently was renamed to be the National Institute for Food and Agriculture (NIFA). This regional study is located in the northeastern region of the United States and includes the states of New Hampshire, Maine, Vermont, Rhode Island, and Connecticut.

This research project is a multiple university trans-disciplinary project integrating different academic fields into a cohesive effort, and is quite novel in its subject, extent, and multifaceted collaboration. The universities involved include the University of New Hampshire, the University of Maine, the University of Connecticut, the University of Rhode Island, the University of Vermont, and Plymouth State University. This project involves the integration of both soil chemistry and social science research. This project also employs the knowledge, expertise, and efforts of various extension programs throughout the region for guidance and implementation. This group corroborates the scope and complexity of the issue at hand, and the necessity of having such a diverse interdisciplinary team.

Many beneficial research and extension outcomes are expected as a result of this project. The soil science research was used to develop regionally specific recommendations for fertilizer use to minimize negative water quality impacts. The social science research looked into lawn care behaviors, the underlying factors that drive that behavior, the correlates of environmentally responsible behavior, and important considerations for program delivery. Additionally the level of trust and influence of opinion leaders (e.g. Master gardeners, local garden centers, mass media) and the relative influence of different types of informational messages was assessed. This research was instrumental in determining how best to facilitate behavioral change by elucidating target "problem" behaviors, better understanding the attitudes and concerns of the audience, guiding the development of appropriate messaging, and discerning the best avenues for information dissemination. Based on the research, outreach and education messages and delivery methods recommendations were developed for extension.

1.3. Work in the Bangor Area

This report presents the work that has been conducted in the Bangor Area of Maine, as part of the *Changing Lawn Care Behavior to Reduce Nutrient Runoff in New England's Urbanizing Watersheds* project and partnering with the University of Maine Extension Services, and the Bangor Area Stormwater Group (BASWG). A behavior change outreach and education campaign was developed and implemented throughout the communities of Bangor, Brewer, Veazie, Hampden, Milford, Old Town, and Orono. All the campaign materials, and dissemination methods, were guided by key findings from an initial region wide study of community lawn care behavior. The campaign material can be viewed in the appendix of this report.

Figure 2: Map of Bangor Area

Additionally a project evaluation study was conducted after the implementation of the outreach and education campaign. This evaluation was conducted to establish whether changes in knowledge, attitudes, and behavioral intention has occurred, and to test overall campaign effectiveness. In addition, this evaluation study included a test of normatively framed messaging to see if this method could improve desired outcomes. This report includes discussions of the results of this study, lessons learned, and presents ideas for improving campaign effectiveness. This evaluation study will seek to answer the following research questions:

Evaluation Study Research Questions:

1. *Was the outreach and education campaign successful at encouraging behavioral change?*
2. *Do normative framed messages have a greater impact than messages excluding the use of norms?*
3. *What aspects of the campaign could be improved upon to progress overall effectiveness?*

2. Using Social Norms to Change Behavior

2.1. Lawn Care Social Norms

An immaculate lawn is considered by many to be a civic responsibility and a necessary component of neighborhood living (Steinberg, 2006). As suggested by Shern et al. (1994) lawns are valued for aesthetic, psychological, normative, and economic reasons. Much of this desire to maintain a socially acceptable lawn may be explained by various psychological factors that have been theorized to drive behavior, such as values, attitudes, sense of responsibility, and particularly social norms (e.g. Ajzen and Fishbein 1980; Thogersen 2006; Cialdini et al. 1990). For example, homeowner's commonly feel a sense of responsibility to adhere to their neighborhood's standard of lawn care, which could also be defined as the neighborhood norm. Furthermore, if this individual decides to deviate from this norm, social sanctioning from the neighbors who do fit the norm may ensue (Robbins 2007).

The degree to which lawn norms impact people's decision and behaviors can be profound. As demonstrated by Robbins (2007), many people who intensely manage their lawns with lawn chemicals are often more likely to be aware of the negative environmental impacts caused by these chemicals than the general population. Furthermore, many of these same people express great concern for the environment. Of these seeming conflicting values, the desire to fit the norm and maintain a suitable lawn takes precedence over environmental responsibility. Well aware of the consequences, these people often choose to perform a behavior that they know could potentially cause harm to the members of their household and the environment.

The desire for a "perfect" lawn is indeed deep-rooted in American culture and involves complex socio-psychological issues, such as influential social norms, that drive lawn care behaviors. Empirical social science research, that can elucidate behaviors as well as the factors that drive behavior, is needed to understand this phenomenon. This understanding will better equip behavior change practitioners to influence meaningful behavioral changes that will reduce NPS pollution and ultimately lead to a healthier environment.

A *social norm* is a shared cultural expectation of behavior that connotes what is considered appropriate and desirable for a given situation

2.2. Using Norms in the Campaign

A *social norm* is a shared cultural expectation of behavior that connotes what is considered appropriate and desirable for a given situation (Scott and Marshall 2005). In other words is a set of beliefs about what people are and should be doing. For example, homeowners may believe that their neighbors apply large amounts of lawn chemicals to their lawns (beliefs about what people are doing) and as a member of a community they also might be expected to produce a suitable lawn (beliefs about what should be done). Many recent studies have found that using social norms in behavior change campaigns concerning environmental issues is a power tool that is able to significantly improve desired outcomes (Griskevicius 2008; Mckenzie-Mohr and Smith 1999). For example, norm based campaigns intending to generate environmentally responsible behavior have been used to encourage towel reuse at major hotels (Goldstein et al. 2008), prevent littering (e.g. Kort et al. 2008; Kallgren et al. 2000; Cialdini 1991), increase curbside recycling (e.g. Schultz 1998; Hopper and Nielsen 1991), encourage the purchase of organic foods (Gotschi et al. 2010), and to reduce household energy consumption (e.g. Schultz et al. 2007).

Norm focused campaign messaging has a lot of merit for creating successful outreach and education campaigns aimed to encourage environmentally responsible behavior. In the article *A Focus of Normative Theory: When Norms Do and Do Not Work* the authors state that, "Our data suggests that including strong normative elements in campaign messages may well be effective in creating desirable conduct" (Kellgren et al 2000, pp. 1011). Much research has gone into understanding how social norms influence behavior and how they can be used effectively by practitioners. Social norms, when used correctly can be an effective and low cost tactic to utilize with behavioral change campaigns. Additionally, American lawn culture provides an intriguing milieu to further test the use of normative influences in a new context.

3. Evaluation Study

3.1. Methods

A self-administered questionnaire was administered door-to-door in six neighborhoods throughout the Bangor Area. Each of the six neighborhoods was randomly assigned one of three treatments; control, standard messaging, and normative messaging. The normative messaging group and the standard group received all of the campaign material (doorhanger, stencils, and reference to the website) while the control group received no material. The normative message group, however, received a variation of the doorhanger where the content was altered to elicit lawn care norms and encourage participation in this norm. The norm used here was that most neighbors choose not to use fertilizers and pesticides on their lawns (a finding elucidated from the initial research conducted as part of the *Changing Homeowner's Lawn Care Behavior to Reduce Nutrient Runoff in New England's Urbanizing Watersheds* project). See the appendix to view the two versions of the doorhangers used, as well as an example of the stencil.

The methods employed by this study (assigning three treatment groups and comparing differences among groups), known as the experimental design method, was chosen over another common evaluation study method called the pre-test/pot-test method. The pretest/posttest method requires the implementation of two tests, a pre-test (administered prior to campaign implementation) and a post-test (administered after campaign implementation). The experimental design method only requires a onetime survey administration and still allows for comparisons to be made between the groups and is an effective means of determining campaign effectiveness while answering the research questions. See Neuman (2007) for a more detailed explanation of the benefits to using the experimental design method with social science research.

The six neighborhoods were purposively selected using criteria appropriate for the survey methodology and the desired outcomes of the study. All the neighborhoods were selected using local knowledge and were all high amenity suburban communities with heavily managed lawns. These neighborhoods were also chosen to be spatially diffuse to prevent "overflow" of campaign exposure. It is imperative to the study that neighborhood are only exposed to their intended treatment as not to botch the comparisons that will be made between neighborhoods.

Given the relatively small population size, the nature of the research questions, and the logistics of campaign delivery the drop-off/pick-up method was deemed best for this study. With this method researchers personally deliver the questionnaires and cover letters door to door to the homes in the study neighborhoods. Respondents were instructed to complete the questionnaire and hang it on their doorknob in a provided bag during established pickup times when the researchers would return to collect the completed questionnaire. This method has proven to yield very high responses rates, be appropriate for small sample sizes, and work to develop relationships between researchers and community members. Additionally, this method works will with the experimental design method allowing for control of coverage that would be more difficult for mailed or internet surveys (Steele et al 2001). This survey also employed many techniques outlined in the Tailored Design Method (Dillman et al. 2009) intended to enhance response rates including customizing letters, using multiple waves of contacts with carefully timed reminders, and providing clear information about the need for responses.

3.2. Results

The six neighborhoods that were selected for this study included anywhere from 31 to 54 homes with a total of 244 homes included in the study. Two neighborhoods received the standard campaign messaging, two received the normative messaging, and two were used as controls and received no campaign material. The neighborhood response rates ranged from 75% to 31%, with an overall combined responses rate of 57%, which is slightly below the expected response rate for this type of survey at around 65% (n=139) (Steele et al. 2001). This slightly lower than desired response rate can in part be attributed to a snow/wind storm that complicated collection and resulted in several completed questionnaires being lost. Figure 3 below shows the summary for total questionnaires delivered and returned for each neighborhood.

Figure 3: Response Summary

Neighborhood	Treatment	Total attempted	Total refused	Total returned	Response rate
Main Trail	Control	40	0	30	75
Mt. Hope	Control	39	1	25	64.1
Francis	Norm	31	2	20	64.5
Judson Heights	Norm	45	3	26	57.7
Constitution	Standard	54	2	27	50
Hillside	Standard	35	6	11	31.4

<u>Intention to Reduce the Use of Lawn Chemicals</u>

Intention to reduce the use of lawn chemicals was assessed across the three treatment groups to compare for differences. A one-way analysis of variance (ANOVA) test with performed to statistically analyze the responses. ANOVA tests how much the mean values of a numerical variable differ among the categories of a categorical variable. In this instance, the numerical variable is the intention to reduce either fertilizer or pesticide use and the categorical variable is treatment type (standard, norm, and control). In addition a tukey LSD post hoc test was performed so that comparisons across groups could be determined, included mean differences and statistical significance (see figure 4). The tukey LSD shows the relationship of each group and indicates what groups means differ from one another, where as ANOVA simple shows the significance between treatment groups and intention. This post hoc test is essential to this analysis since comparing the differences between each treatment group is essential to the evaluation study.

Figure 4: Post Hoc ANOVA Results: Treatment Type Compared to Intentions

Dependent Variable	(I) Treatment type	(J) Treatment type	Mean Difference (I-J)	Std. Error	Sig.
Intention to fertilize	Standard	Norm	.14382	.11746	.223
		Control	-.09472	.11240	.401
	Norm	Standard	-.14382	.11746	.223
		Control	-.23854*	.10356	.023
	Control	Standard	.09472	.11240	.401
		Norm	.23854*	.10356	.023
Intention to pesticide	Standard	Norm	.18889	.12178	.124
		Control	-.11111	.11687	.344
	Norm	Standard	-.18889	.12178	.124
		Control	-.30000*	.11348	.010
	Control	Standard	.11111	.11687	.344
		Norm	.30000*	.11348	.010

This analysis indicates that according to the differences in mean scores, the standard group is more likely to intend to reduce or eliminate both fertilizer and pesticide use than the control group. Furthermore, the norm group is more likely to intend to reduce or eliminate both fertilizer and pesticide than the standard. The relationship was the desired outcome for this project and indicates that our efforts are having effects in these neighborhoods. Also, the differences between the norm groups and the control groups revealed statistical significance, at a level of .023 for intention to reduce fertilizer use and .01 for intention to reduce pesticide use, revealing a clear difference between these groups (remember that statistical significance is a value of .05 or less). The evidence is clear that the neighborhoods receiving normatively framed messages were the most likely to express intention to reduce lawn chemical use, and future messaging should be developed with this finding in mind.

<u>Exposure to the Campaign</u>

Questions were asked concerning whether or not neighborhood residents have been exposed to any of the campaign materials including the doorhanger, the stencils, and the web material. The results of this evaluation study indicate that both the doorhangers and the stencils were highly visible in these neighborhoods, see figures 5 and 6. However, the website was rarely visited, highlighting an area for improvement for this campaign (see figure 7).

Figure 5: Exposure to Doorhangers by Treatment Type

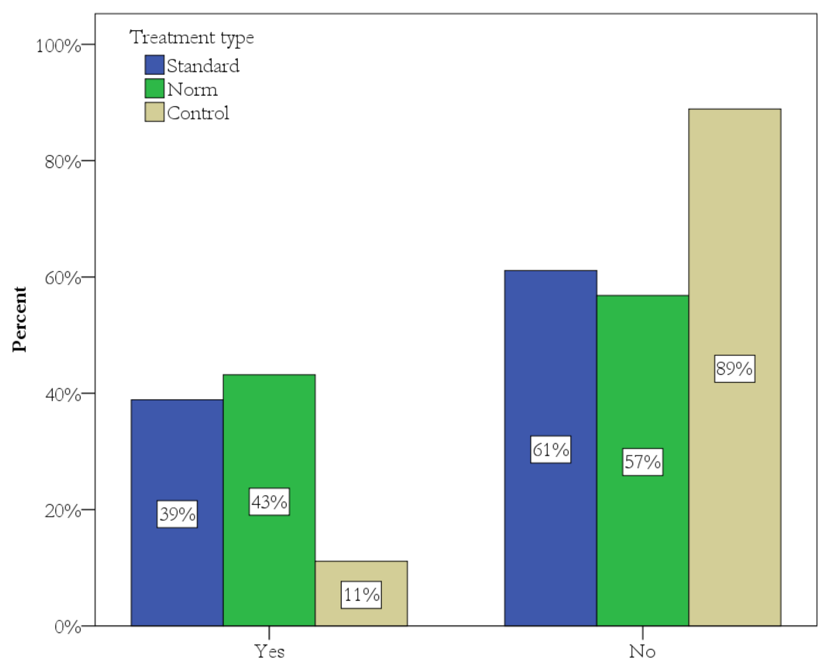


Figure 6: Exposure to Stencils by Treatment Type

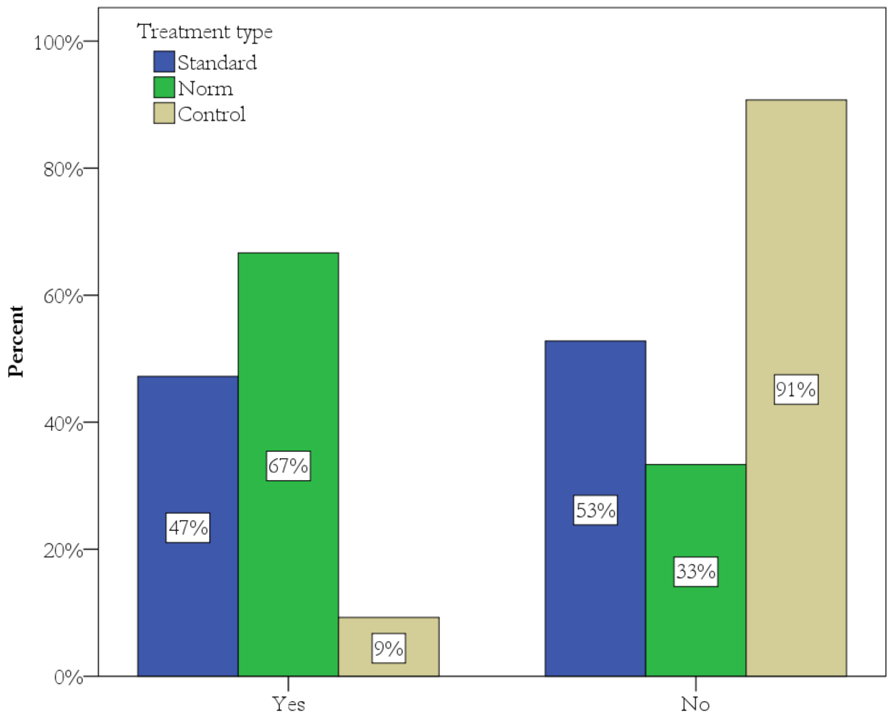
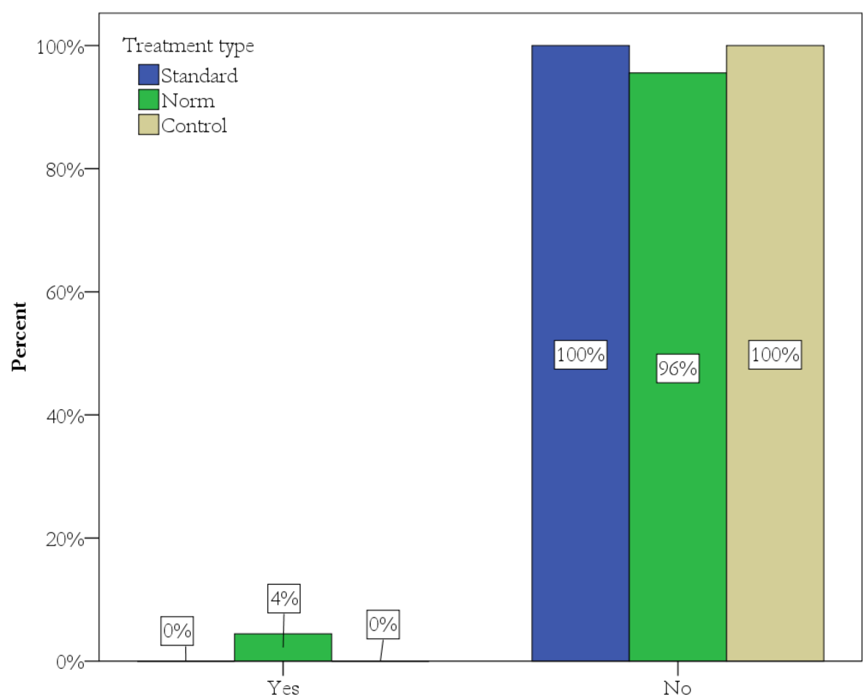


Figure 7: Exposure to Website by Treatment Type



Furthermore respondent were asked if they had seen or heard about any BASWG activities or information from the following media sources: newspaper, television, radio, internet, and a fill in the blank "other" option. Very few of the respondents indicated that they had seen or heard any BASWG activities. The most notable results are: 11% of respondents indicated they had seen BASWG on television and 5% saw us in the newspaper. Responses for the "other" category include: at a local fair, at work, and from a friend.

<u>Neighborhood Perceptions of Lawn Care Issues</u>

A series of questions were asked concerning how respondents think their neighbors maintain their lawns and what the neighborhood attitudes are concerning lawn care behavior. This information can be useful to determine what the neighborhood standards of lawn care are, and how this might be used to direct future campaign efforts. Despite my hopes, statistical analysis reveals no meaningful differences across the three treatment groups. Therefore these questions will be analyzed using the total population, rather than treatment by treatment. This also indicates that despite the normative messaging presented to the two norm treatments, those respondents were not more likely to acknowledge the presented norms.

Most respondents either disagree or strongly disagree that people in their neighborhood choose not use fertilizers and pesticides on their lawns. This is affirmed in figure 8 (next page) showing that most respondents agree or strongly agree that most of their neighbors use lawn chemicals. This is indicative of the perceived prevalence of lawn chemical use, and should be a target for future outreach and education campaigns. Additionally most respondents indicated a high concern for protecting water quality in their neighborhoods see figure 9 (next page). These results are similar to the results found be Robbins (2007) where residents express concern for the environment, yet still choose to apply deleterious chemicals.

Figure 8: Level of Agreement that Most Neighbors Use Lawn Chemicals

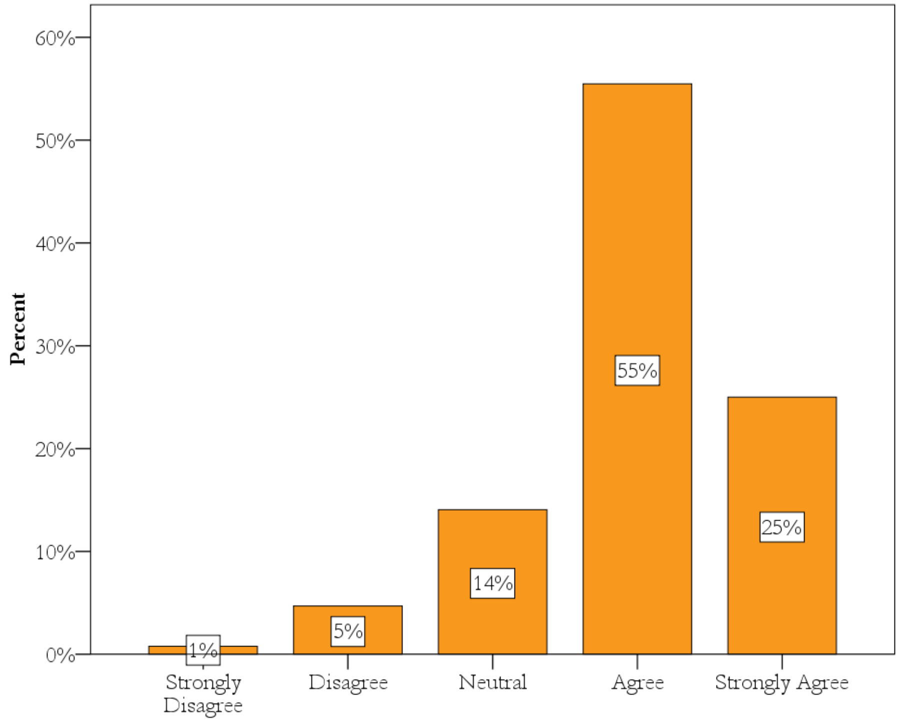
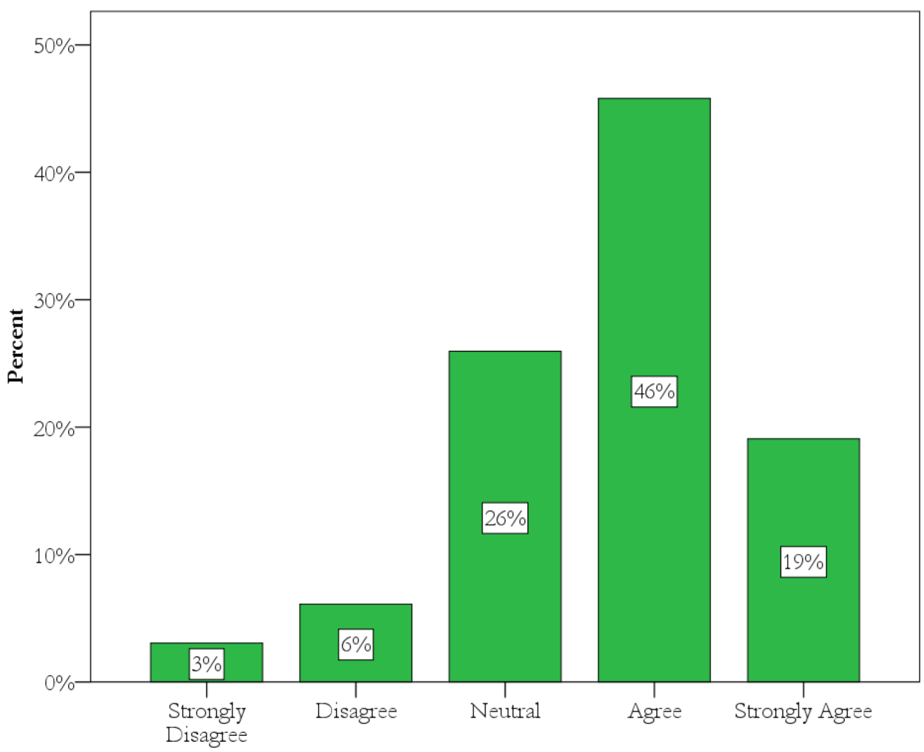


Figure 9: Level of Concern for Water Quality



How often do you Apply Lawn Chemicals?

Questions 3 concerned how much lawn chemicals are applied to the respondent's lawn. After performing statistical analysis, no significant differences were discerned between treatment groups. Therefore this section is also analyzed at the whole sample level. Most residents of these neighborhoods indicated that they apply fertilizers, pesticides, and combination weed and feed products at least 1 time a season. Pesticides however, had the highest percentage of respondents indicating that they did not apply at nearly 50%, see figure 10. Fertilizer application is very common in these neighborhoods as can be seen in figure 11, with many respondents applying more than once a year. Weed and feed products are also quite popular, again with many respondents applying more than once a year. These results are slightly different than those of the initial lawn care study which found that most people actually do not apply fertilizer to their lawns.

Figure 10: Number of Pesticide Applications Last Season

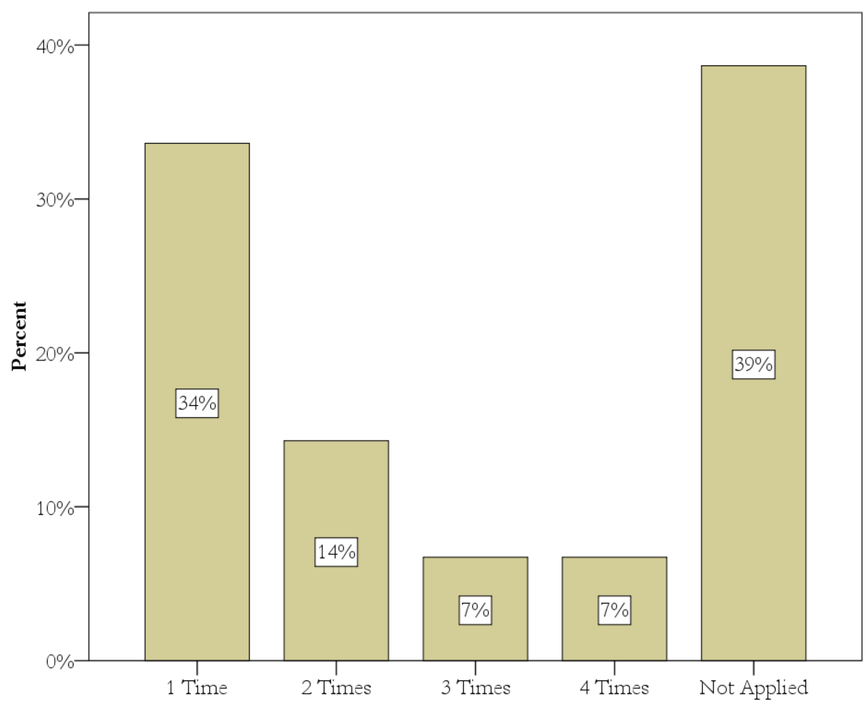
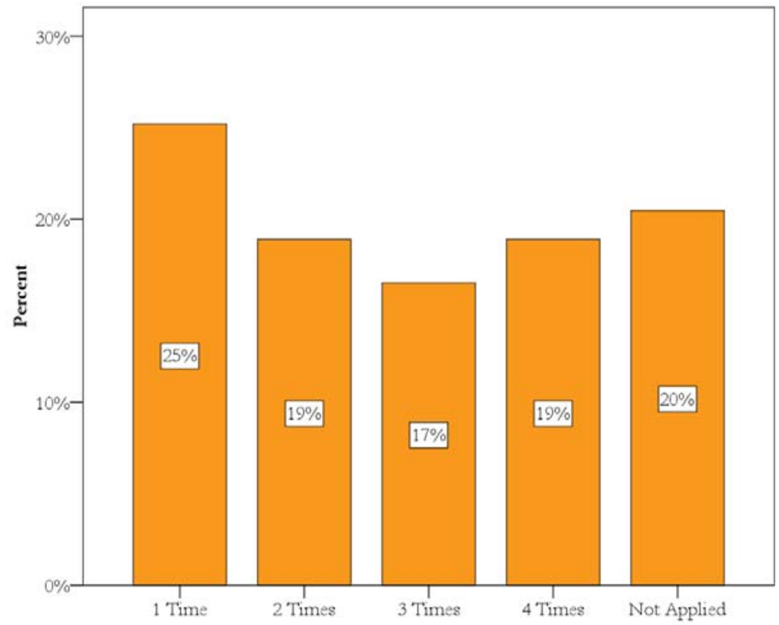
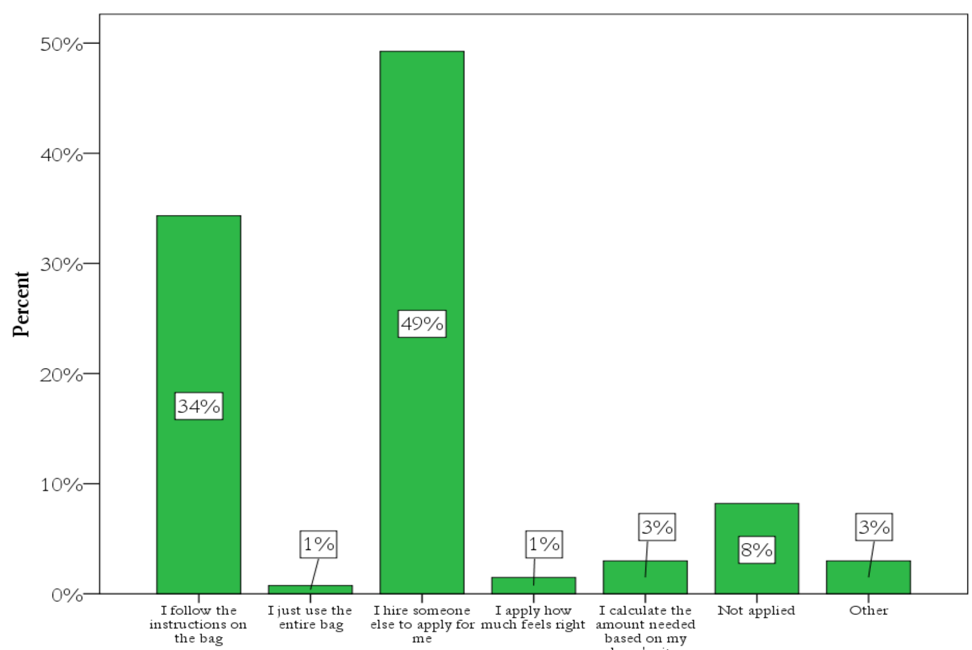


Figure 11: Number of Fertilizer Applications Last Season



An additional question asked what method respondents use to determine how much lawn chemicals to apply. Most notably, 49% of respondents hire someone to apply their chemicals for them and another 34% follow the instructions on the bag, while the other methods presented are only marginally used (see figure 12 below).

Figure 12: How Respondent's Determine How Much to Apply



Knowledge about nutrient runoff

Questionnaire items were included to test respondents knowledge about the adeverse affects of lawn chemicals to the envrionment. After statistical analysis, no significant differences were found across groups. This finding is unfortunate in that I was hoping differences would be found and we could assert that our campaign increased knowledge signigicantly, perhap explaining the differences in intention. As can be seen in figure 13 and 14 the vast majority of repsondents agree or strongly agree that lawn chemicals can cause harm to kids (84%) and pets (88%). These high levels of agreement acorss the board indicate that there is likely preexsiting knowledge of potetial harm to kids and pets, and while our campaign material may in fact be increasing knowledge this change is not explained strongly by the data.

Figure 13: Level of Agreement that Lawn Chemicals can cause Harm to Kids

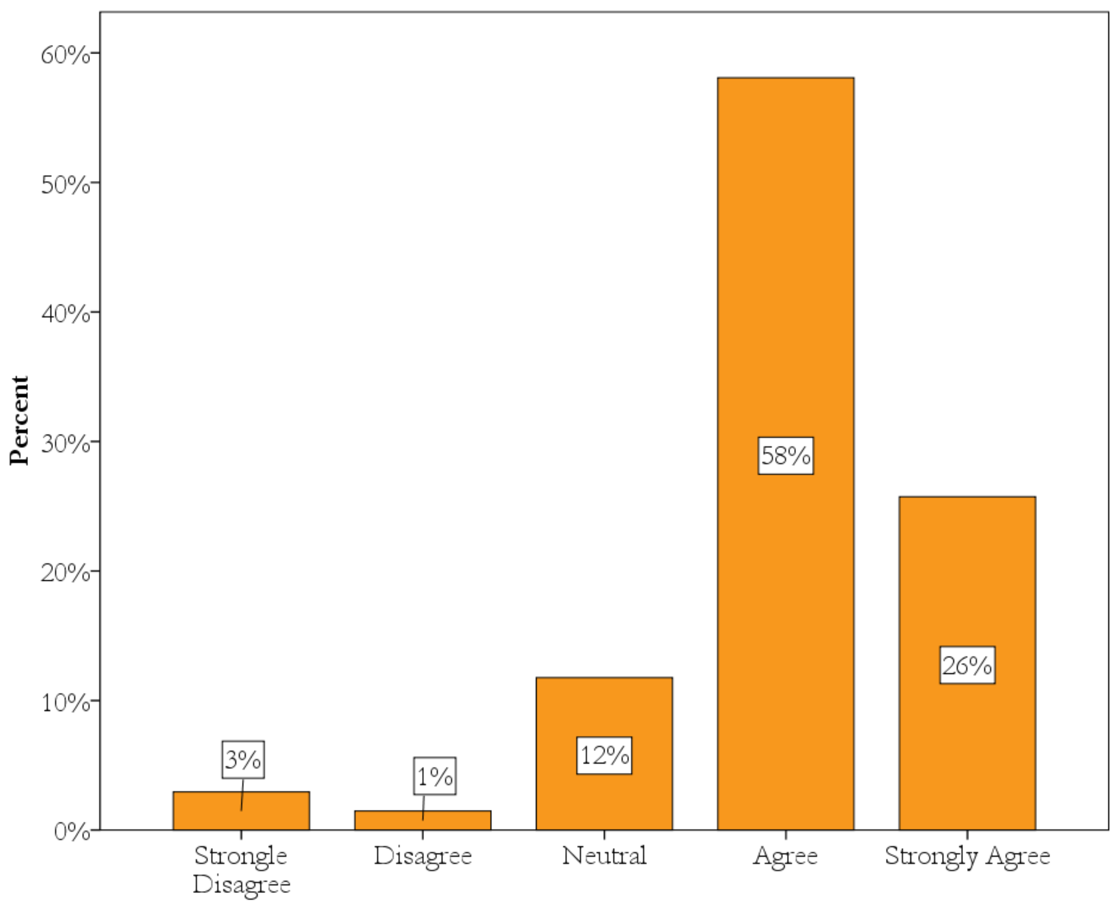
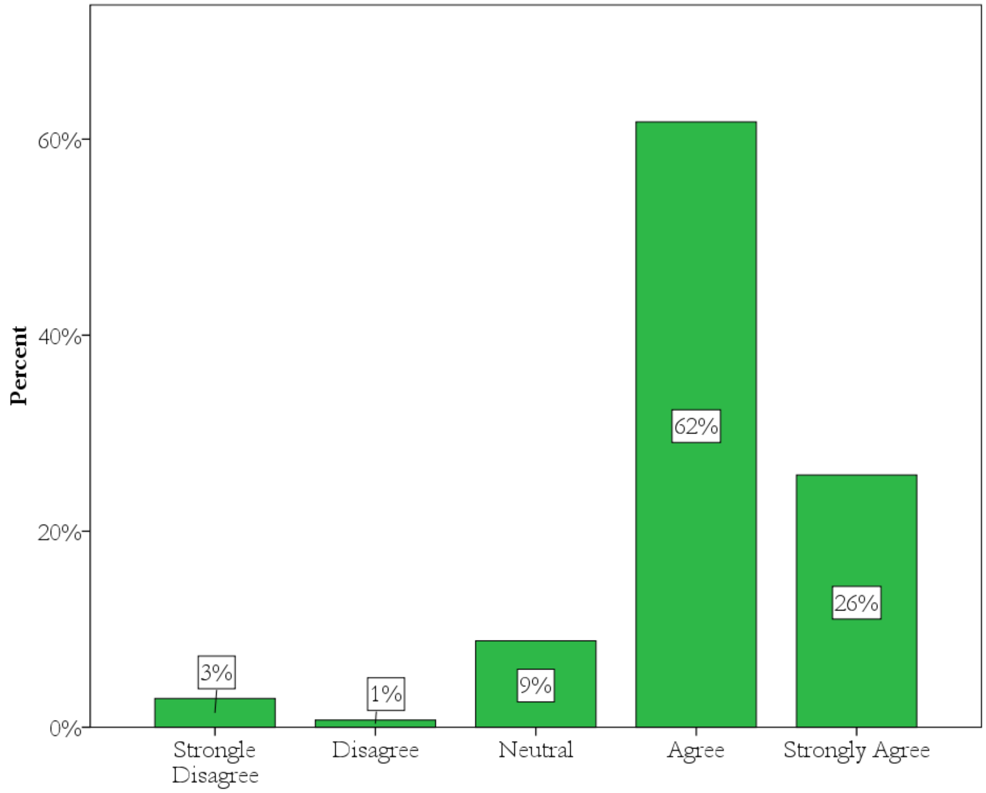


Figure 14: Level of Agreement that Lawn Chemicals can cause Harm to Pets



Respondents were asked if they agree that lawn chemicals do not affect have negative impacts on water quality. The majority of respondents either disagrees or strongly disagrees with this statement at 66% (see figure 15). Another 26% indicated that they were neutral so perhaps these respondents, and those who disagree with this statement, could be targeted for future educational campaign making the link between lawn chemical use and potential affects to local water quality. Additionally, respondents were asked if agree that lawn chemicals can runoff into local waterways, see figure 16. Most respondents (88%) agree or strongly agree that chemicals can runoff into waterways. These findings suggest that most respondents have a preexisting understanding that lawn chemicals can runoff into waterways and negatively affect water quality. While this information should not necessarily be excluded from future material, the data suggests that putting an emphasis on other information, such as shifting norms, to facilitate change may be more effective.

Figure 15: Level of Agreement that Lawn Chemicals do not affect Water Quality

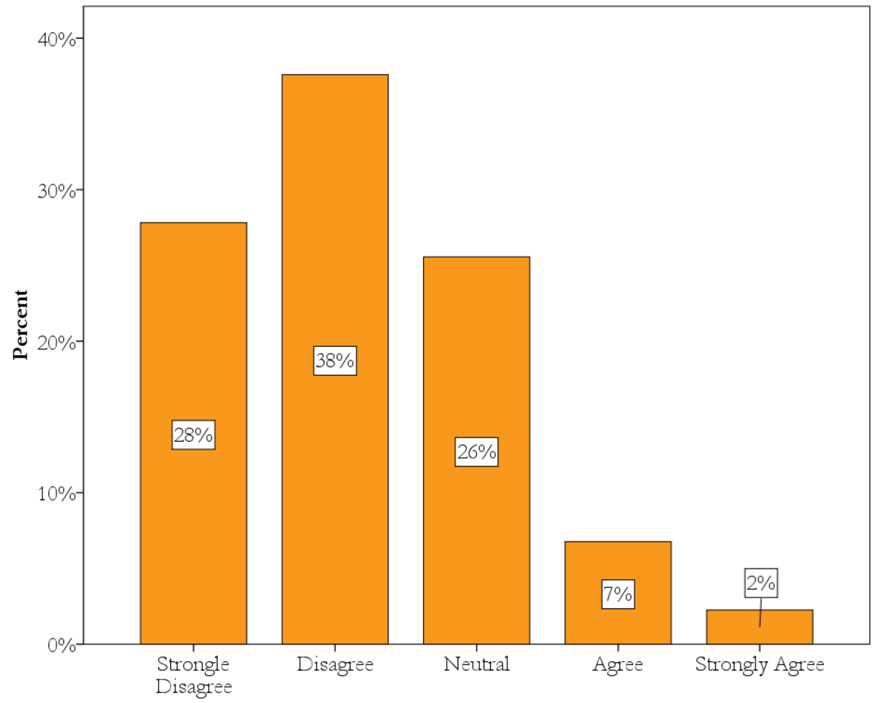
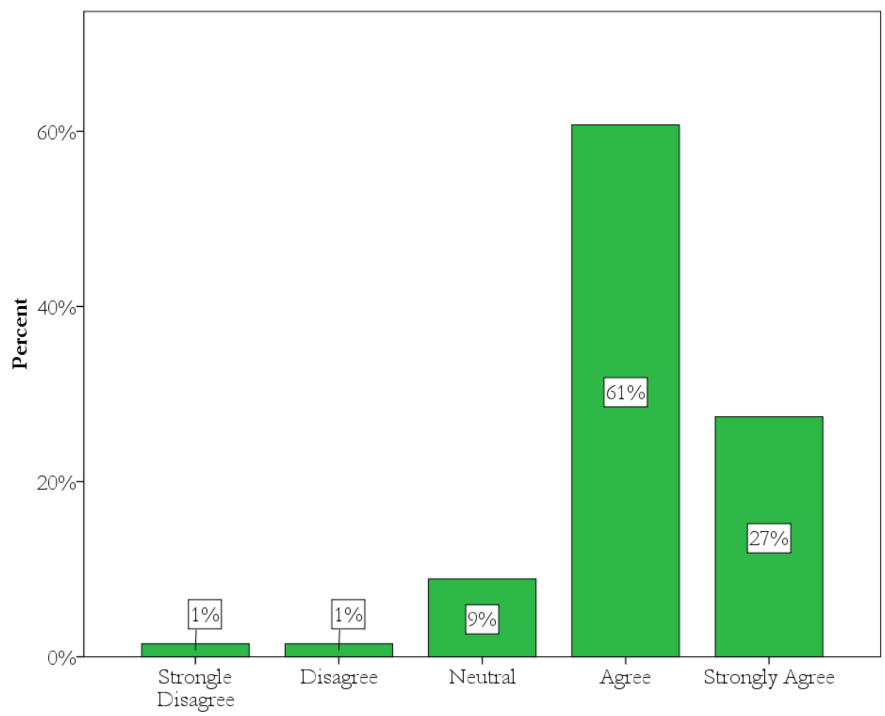


Figure 16: Level of Agreement that Lawn Chemicals can Runoff into Local Waterways



<u>Demographics</u>

Demographic questions were included in the questionnaire so that responses from people of differing background characteristics could be compared to identify any important trends across groups. In this case statistical analysis revealed no significant demographic differences within the sample. However, when compared with census data, some notable differences can be seen between our sample and averages for the state of Maine. For example, these neighborhoods are in a higher income and education bracket than typical for Maine (www.factfinder.census.gov). This was expected since these neighborhoods were selected to be high-amenity. This may explain some of the discrepancy between the initial lawn care study and this evaluation study, where in the initial study the norm was not to apply and in this study the norm is to apply. These results suggest those high amenity neighborhoods are more likely to apply lawn chemicals, which supports a recent study correlating lawn expenditures and lawn greenness by Zhou et al. (2009). This also affirms those high amenity neighborhoods are a good target for future campaigns aimed to reduce the use of lawn chemicals.

Another finding from the demographics section of this study found that 54% of the respondents have lived in their communities for 5 or less years. Some of the neighborhoods in the study area are newer developments (e.g. Mt. Hope and Judson Heights). Perhaps many homeowners' in these neighborhoods are attempting to establish new lawns and this could explain the higher frequencies of lawn chemical application.

4. Summary

Many respondents from the sampled neighborhoods do indeed use lawn chemicals as part of the lawn management behavior. Our efforts have shown to be successful at changing intention to apply lawn chemicals next season. Additionally, the use of normative framed messaging has proven to have a greater impact than messages without this framing. Future campaigns are needed to continue to affect people's lawn care decisions and norms can be a powerful tool.

As was the case with the initial lawn care survey, this evaluation found that most people get their lawn chemical application information from the product packaging. This affirms the need for point of sale products in place in stores, as well as a continuation of education and outreach. This is a great place for the dissemination of the site specific fertilizer recommendations developed from the soil science component lawn care project.

Many respondents in these neighborhoods utilize lawn care services. It would behoove us to consider this issue with both homeowners and lawn care service providers to encourage the use of more environmentally responsible lawn care techniques. Additionally, as affirmed in this study and the initial study, there is an expressed concern for water quality, lawn care alternatives which still maintain the community's standard of lawn care need to continue to be encouraged.

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This material is based upon work supported in part by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement Nos. 2008-51130-19504 and 2006-51130-03656. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture. This project developed with the support and collaboration of the Department of the Interior, U.S. Geological Survey and the Senator George J. Mitchell Center at the University of Maine, under Grant No. 06HQGR0089.

Changing Bangor Area Lawn Care Behavior

Evaluation Survey: Appendix



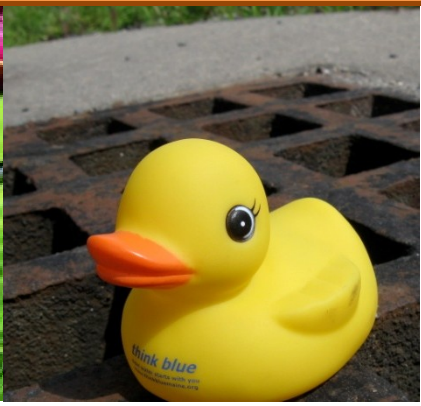

Table of Contents

1. Products

1.1. Standard Doorhanger Outside

1.2. Standard Doorhanger Inside

It's Easy to Reduce Your Use of Lawn Chemicals:

1 **Fertilize?**- Mow high and just leave the clippings on the lawn. If you have to fertilize look for phosphorus free or ask your local retailer and apply in late August.

2 Got Weeds?- Try spreading perennial ryegrass on your lawn. Repeat as needed throughout the growing season.

3 **Got Bugs?**- Spread insect resistant fescue grasses in problem areas or learn about other safe and healthy methods at www.BASWG.org

4 Weed and Feed?- Avoid combination products that contain both fertilizers and pesticides.

Chemicals from lawns and streets in **your neighborhood** run off into the storm drains identified on this map as ducks. The water from these storm drains then flows into the Penobscot River.

For more information visit www.BASWG.org.

1.3. Normatively Framed Doorhanger Outside

1.4. Normatively Framed Doorhanger Inside

Easy steps your neighbors have used to reduce their use of lawn chemicals

1. **Fertilize?**
Mow high and just leave the clippings on the lawn. If you have to fertilize look for phosphorus free or ask your local retailer and apply in late August.

2. **Got Weeds?**
Try spreading perennial ryegrass on your lawn. Repeat as needed throughout the growing season.

3. **Got Bugs?**
Visit pmo.umext.maine.edu/homeowner, or call the University of Maine Cooperative Extension's Pest Management experts at 581-3880.

4. **Weed & Feed?**
Avoid these combination products that contain both fertilizers and pesticides.

Chemicals from those few lawns in **your neighborhood** that use too many lawn chemicals run off into the storm drains identified on this map as squares. The water from these storm drains then flows into the Penobscot River. Even a small amount of lawn chemicals in runoff can adversely affect water quality.

For more information visit www.BASWG.org.

1.5. Stencil Example

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2009ME186B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	John M. Peckenham, John M. Peckenham

Publications

There are no publications.

Maine WRRI IT FY09

Publications

Peer- Reviewed Journal Articles

Flinders, Camille A. and D. Hart. 2009. Effects of pulsed flows on nusance periphyton growths in rivers: a mesocosm study. River Research and Applications, 25:10, 1320-1330.

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Reports

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Nelson, S.J., 2009. Mercury concentrations in northeast lakes predicted using landscape features, landscape setting, and water chemistry. Final "Project Impacts" report to NSRC.

Other Publications

Online Publications

Mitchell Center newsletters are published on-line and include news and information on current activities at the Mitchell Center and Maine's Water Institute. The newsletter is emailed to over 2,000 subscribers including over 1,400 external constituents.

Waterlines…in brief. Web−based news sheet, March 15, 2009.
http://www.umaine.edu/waterresearch/outreach/in_brief_3_09.htm

Waterlines…in brief. Web−based news sheet, March 27, 2009.
http://www.umaine.edu/waterresearch/outreach/in_brief_3_09_II.htm

Waterlines…in brief. Web−based news sheet, April 16, 2009.
http://www.umaine.edu/waterresearch/outreach/in_brief_4_09.html

Waterlines…in brief. Web−based news sheet, May 4, 2009.
http://www.umaine.edu/waterresearch/outreach/in_brief_5_09.html

Waterlines…in brief. Web−based news sheet September 9, 2009.
http://www.umaine.edu/waterresearch/outreach/in_brief_9_09.html

Waterlines…in brief. Web−based news sheet, February 10, 2010.
http://www.umaine.edu/waterresearch/outreach/in_brief_2_10.html

Publications for Lay Audiences

Zoellick, B, Nelson, S., Davis, Y. 2009. Teachers' Guides to Mercury in Maine's People and Ecosystems. A series of six curriculum units, published online, www.acadialearning.org.

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Presentations

Academic Presentations

Nelson, S.J., 2009. Finding mercury in Maine: Local, regional, and global influences. Maine Maritime Academy lecture series, Dec. 7, 2009; Husson University, March 29, 2010.

Peckenham, John (2009) Water quality information for decision support: A tale of two datasets, Maine Water Conference, March 24, 2009.

Jain, S., J.-S. Kim, A. Sen Gupta, and K. Ricupero, Incorporating hydroclimatic variations and change into water allocation policy making and adaptation, Climate Change: Global Risks, Challenges and Decisions, 10-12 March 2009, Copenhagen, Denmark.

Ricupero, K. and S. Jain, Sustainable water allocation and instream flow policy in the New England Region: understanding the implications of climatic variability and change. EPA-UMaine Mitchell Center Sponsored Drinking Water Workshop, Wells, Maine. April 2009.

Tylka, M.L., Vaux, P., Bell, K.P. 2009. Trends in Water Clarity of Maine's Great Ponds. Graduate Expo, University of Maine, Orono, ME, April 14, 2009.

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National and International Meetings

Nelson, S.J., Zoellick, B., Davis, Y., Lindsey, E., 2009. The Acadia Learning Project: Lessons Learned from Engaging High School Teachers and Students in Citizen Science Supporting National Parks. Submitted to American Geophysical Union Fall Meeting, Dec. 14-18, 2009, San Francisco, CA.

Nelson, S.J., K.B. Johnson, 2009. Are We Under-Estimating Mercury in Soils? Experimental Acidification and Sample Collection Timing Demonstrate Variability in Estimates of Mercury in O-Horizon Soils at a Maine Site. Submitted to American Geophysical Union Fall Meeting, Dec. 14-18, 2009, San Francisco, CA.

Presentations for Lay Audiences

T. Johnson, S.J. Nelson. Dealing with data. Workshop for high school teachers. Bangor, ME, Jan. 30, 2010.

S.J. Nelson, B. Zoellick, Y. Davis. Acadia Learning Program. Workshop for high school teachers, Winter Harbor, ME, 2009.

T. Johnson, S.J. Nelson. Dealing with data. Workshop for high school teachers. Bangor, ME, Jan. 30, 2010.

S.J. Nelson, B. Zoellick, Y. Davis. Acadia Learning Program. Workshop for high school teachers, Winter Harbor, ME, 2009.

S. J. Nelson. Career and Technical Education Teachers workshop, Schoodic Education and Research Center, June 29, 2009.

Peckenham, J. GET WET! Drinking Water Quality and Private Wells. Presented to Lamoine Consolidated School, Ellsworth High School and Wagner Middle Schools. Ellsworth and Winterport, Maine. March-April 2010.

Conferences and Annual Meetings

Maine Water Conference 2009

The 2009 Maine Water Conference took place on Tuesday, March 24, 2009 in conjunction with the annual meeting of the Northeast Geological Society of America (NEGSA) at the Holiday Inn in Portland, Maine. This provided a much larger, more regional audience than the Maine Water Conference usually attracts. The conference followed the NEGSA format that included morning and afternoon sessions with no plenary. Session topics provided a more regional focus to meet the needs of the wider audience.

The Maine Water Conference is the largest environmentally-related conference in Maine attracting over 350 water resource professionals. It provides unprecedented opportunities to promote both the Mitchell Center’s and UMaine’s role in environmental research and problem-solving throughout Maine and to build stronger relationships with state and federal agencies, NGOs, and the private sector. The MWC Steering Committee is made up of key water resource stakeholders from across the state.

Sponsorship for the 2009 Maine Water Conference was provided by: U.S. Geological Survey, Senator George J. Mitchell Center for Environmental and Watershed Research and the Maine Water Institute, Maine Drinking Water Program/Dept. of Health & Human Services, Aqua Maine, Maine Dept. of Environmental Protection, Maine WasteWater Control Association, Maine Congress of Lake Associations, and University of Maine Cooperative Extension.

Public Service

Media/Press

Salting Roads Before Snow May Save Lives. Bangor Daily News, February 10, 2010

S. Nelson, Mercury in snow at Acadia National Park reveals watershed dynamics. PARKScience Online, July 10, 2009.

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 (~500 students on the river)
- GET WET! (~125 students, water quality testing).
- 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
- DEP-Consulting Engineers of Maine Task Force
- New England Water Quality Extension Advisory Board

Sarah Nelson

- Co-convener, AGU fall meeting (2 sessions regarding mercury biogeochemistry), December 2009
- 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, 2006-present
- Coordinator, University of Maine Mercury Research Group, 2006-present
- Board member, Maine Lakes Conservancy Institute
- Maine Water Conference Organizing Committee

Peter Vaux

- Board member and Treasurer, Maine Volunteer Lake Monitoring Program
- Development of databases and on-line data resources Union River Watershed

Workshops and Other Activities

Maine's Sustainability Solutions Initiative (SSI) at the Mitchell Center

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. This initiative grew out of the Environmental Solutions Initiative (ESI), an earlier Mitchell Center program. Creating synergy between the Maine WRRI program and ESI was always a priority as reflected in some of the projects funded under ESI – Conserving Vernal Pools through Collaborative Local Initiatives, Land Use Change in the Lower Penobscot Watershed, Tracking Stormwater Quality Using Real-Time In-Situ Fluorescence. This synergy continues with the founding of SSI providing important leveraging opportunities for water resource projects across the state. It is also important to note that many faculty who have been funded under the WRRI research program are key collaborators on the SSI project.

Introduction to Maine's Sustainability Solutions Initiative

Producing knowledge and linking it to actions that meet human needs while preserving the planet's life-support systems is emerging as one of the most fundamental and difficult challenges for science in the 21st century. There is growing consensus that traditional methods of generating and using knowledge must be fundamentally reorganized to confront the breadth, magnitude, and urgency of many problems now facing society. Maine's Sustainability Solutions Initiative seeks to transform Maine's capacity for addressing these scientific challenges in ways that directly benefit Maine and other regions. The program of research will also help Maine increase economic activity and technological innovation in ways that sustain the State's remarkable "quality of place".

Maine's Sustainability Solutions Initiative Research Projects

The following funded projects provide direct linkages with the Maine WRRI program. Opportunities for further collaborations that enhance both research programs will be actively pursued in the future.

- Linking Knowledge with Action: Refining Maine's Mercury Fish Consumption Advisory
  Team Leader: Aria Amirbahman, Civil & Env. Engineering, University of Maine
- Protecting Natural Resources at the Community Scale: Using population persistence of vernal pool fauna as a model system to study urbanization, climate change and forest management
  Team Leader: Aram Calhoun, Wildlife Ecology, University of Maine
- Decision tools to support water resources sustainability of managed lake systems
  Team Leader: Shaleen Jain, Civil & Env. Engineering & Climate Change Institute, UMaine

- Adaptation Strategies in a Changing Climate: Maine's Coastal Communities and the Statewide Stakeholder Process
  Team Leader: Shaleen Jain, Civil & Env. Engineering & Climate Change Institute, UMaine
- Analysis of Alternative Futures in the Maine Landscape using Spatial Models of Coupled Social and Ecological Systems
  Team leader: Rob Lilieholm, Forest Resources
- Sustaining and Restoring Urban Stream Resources in Maine
  Team leader: Dave Owen, School of Law, University of Southern Maine
- Researching Knowledge-to-Action Linkages to Promote Stakeholder and Community Engagement
  Team leaders: Laura Lindenfeld, Communication and Linda Silka, Margaret Chase Smith Center for Public Policy

SSI Kick-off Event

Former Maine Governor Angus King was the keynote speaker for Maine's Sustainability Solutions Initiative kick-off event in September of 2009. King's talk addressed the role of universities in creating a sustainable Maine. Over 300 people attended the event. President Robert Kennedy provided the opening welcome.

Mitchell Center and SSI Seminars

In order to meet its mission and goals, the Mitchell Center offers related seminars and workshops each semester. Following is a list of relevant seminars for FY09.

April 17, 2009
Politics and the evolution of environmental regulations in Maine
Harold Pachios, Preti Flaherty Beliveau and Pachios

April 28, 2009
Works that Work – Art & Sustainability
Buster Simpson, artist

April 29, 2009
2009 Geddes W. Simpson Distinguished Lecture
Reading and Conserving New England. Using History to Interpret and Manage Nature
David R. Foster, Director of the Harvard Forest

September 10, 2009
Social-ecological systems research: some perspectives on the good, the bad and the ugly
Elena Irwin, Ohio State University

September 28, 2009
The Humane Metropolis: People and Nature in the 21st Century
Rutherford H. Platt, Prof. of Geography Emeritus, UMass & Senior Fellow at the Institute for Sustainable Cities (CUNY)

October 19, 2009
Legal Protection of Biodiversity in Stormwater-impacted Urban Streams
David Owen, University of Maine School of Law

December 7, 2009
Property Rights, Public Goods, and Collective Action: Collaborative Management and Vernal Pool

Conservation Planning in Maine
Jessica Jansujwicz, Ecology and Environmental Science

December 10, 2009
Conserving Maine Vernal Pools Through Collaborative Local Initiatives
Dawn Morgan, Ecology and Environmental Science

December 11, 2009
Smart Growth: Bringing Disciplines Together to Develop Innovative Solutions
Linda Silka, Interim Director, Margaret Chase Smith Policy Center, SSI team member.

December 11, 2009
Meeting the challenge of turning research-based information into societal action: accumulating evidence - old and new.
Jack Kartez, Edmund S. Muskie School of Public Service, USM, SSI team member

January 15, 2010
The Other Inconvenient Truth: A Global Crisis of Land, Food and Environment
Jon Foley, Director, Insititute of the Environment at the University of Minnesota

January 25, 2010
Are we asking to much of the Yukon River? International treaties, Yukon River Salmon, and food security in a changing arctic
Philip Loring, University of Alaska

January 26, 2009
The cultural inventory as an alternative form of public participation in natural resource management
Damon Hall

February 1, 2010
Social Limits on Sustainability: a case study from Tamil Nadu
Tim Waring

February 8, 2010
Rural environmental licensing I Rondonia, Brazil: Insights from systems-dynamics and agent-based approaches
Andrew Bell

February 25, 2010
SSI from a Coastal Perspective
Kristin Wilson, University of Maine

Environmental Seminars at UMaine

As part of a larger initiative to have the Mitchell Center become the focus of environmental initiatives on campus, Center staff worked with other departments and institutes to put together a comprehensive list of all the environmentally-related seminars taking place at UMaine each semester. This initiative has been very well received by staff, faculty and students, and several faculty members noted that this was an important role for the Mitchell Center.

Web Sites

The Mitchell Center hosts two Web sites, the main Mitchell Center Web site (http://www.umaine.edu/WaterResearch/) and the new SSI Web site. WRRI program information is available on the Mitchell Center web site and includes updates on funded projects, grant programs and related conferences and grant opportunities. The site is updated weekly.

The SSI Web site was launched in 2009 (www.umaine.edu/sustainabilitysolutions) and is designed to assist with SSI communication efforts. The site contains information covering many aspects of the initiative including current research projects, faculty and student involvement, student opportunities and recruitment materials, resources, and news and events.

GET WET!

Groundwater Education through Water Evaluation and Testing (GET WET!) is an experiential project to raise community awareness about groundwater quality and to provide data for a study of gravel mining and water quality. There are three key objective categories: science, community, and education.

Scientific goals include:

- Create long-term water quality databases in towns through annual well monitoring and sampling.
- Utilize students to sample. The wells sampled are located in, over, or next to the sand and gravel aquifer.
- Include in the database: 1) Water chemistry of nitrate, alkalinity, chloride, conductivity, and turbidity. 2) Locations of wells mapped into a GIS program. 3) Operational excel spreadsheets with all information gathered. 4) Statistics and charts to graphically represent information.

Community goals include:

- Increase awareness, understanding, and interest in water resources within towns.
- Involve local citizens in the sampling, monitoring, and maintenance of water quality within their town.
- Generate a water quality database that can be used by the community to formulate productive choices in planning, management, and development.

Education goals include:

- Create an interdisciplinary study focusing on natural resources water and development.
- Employ all grades and educators involved in chemistry, geology, geodesy, mapping, GIS, statistics, computer programs, and environmental studies.
- Encourage student development in: 1) Field sampling techniques. 2) Laboratory skills. 3) Computer competence. 4) Internet research capabilities. 5) Mapping abilities in both interpolation of hard copy topographic maps and interpretation of computer based topographic maps. 6) Recognition and identification of locations by latitude and longitude on topographic maps. 7) Comprehension in terminology and function of water chemistry testing for nitrates, alkalinity, chloride, conductivity, and turbidity. 8) Understanding of why conservation and commitment to a healthy environment takes an entire community. 9) Public presentation.

Penobscot River and Bay Institute May−June 2009: Penobscot River Keepers Expeditions.

These day−long canoe expeditions on the Penobscot River provide students in grades 7 to 12 an opportunity to learn about rivers, watersheds, history, and ecology. In 2009 over 450 students took part in the expeditions.

Waterlines…in brief mailings

The Mitchell Center has moved its newsletter almost exclusively to an on-line format (http://www.umaine.edu/waterresearch/outreach/waterlines.htm) with e-mail notification to its subscription list. An effort has been made to keep newsletter content shorter which enables mailing on a more frequent basis. This allows us to provide readers with updates on upcoming seminars, conference and event information, proposal notification and more in a more timely fashion. A total of six "Waterlines…in brief" were distributed in FY09 to a mailing list of over 2,000 readers.

Professional Partnership and Praxis

Sarah Nelson is participating as a partner in the project "Professional Partnership and Praxis: Connecting Teachers, Working Scientists, and College Education Faculty to Attain New Learning Results" through Maine Title II, Mathematics and Science Partnerships program. Although Nelson is involved with all goals of the project through collaboration with Acadia Partners for Science and Learning and other partners, her primary activities relate to planning and design sessions, lesson and research program planning and design, direct engagement between students, teachers, and working scientists, and statewide outreach and invitation to participate.

Research Coordination Network: Diadromous Species Restoration Research Network

The Diadromous Species Restoration Research Network (DSRRN) is an NSF-funded network whose goal is to advance the science of diadromous fish restoration and to facilitate interactions among scientists, managers, and stakeholders. A web site for the network has been established at http://www.umaine.edu/searunfish and a full-time Science Information Coordinator was hired in March 2009. In November 2008, a Stakeholders Workshop was convened to introduce the Network and to gather information to identify research questions and restoration goals. Over 30 stakeholders attended and discussed potential impacts and changes as a result of the anticipated dam removals on the Penobscot River.

In April 2009, the Network hosted the first gathering of the Penobscot Science Exchange. The purpose of the Exchange is to meet biannually to share information regarding research and monitoring in the Penobscot Watershed. Each researcher was asked to provide a two-minute update describing his/her research on the Penobscot. There were also presentations on the NOAA Restoration Monitoring Plan, DMR-BSRFH Operational Plan for Diadromous Species on the Penobscot, Penobscot Trust Project and NOAA Stimulus Proposal, and DSRRN Activities. In addition, the Coordinator reviewed the recently updated Penobscot Science Exchange Research Summary, a database which describes recent research on the Penobscot. Information about both the Stakeholders Meeting and the Science Exchange Meeting can be found at http://www.umaine.edu/searunfish/research/Penobscot-exchange.htm

The first DSRRN science meeting was held in July 2009. This meeting was designed to shape substantial dialog about the future of diadromous species restoration and research and to strengthen the growing network of diadromous species researchers and managers. The meeting featured nationally renowned plenary speakers Margaret Palmer, (University of Maryland), David Montgomery (University of Washington), Gérald Chaput, (Fisheries and Oceans Canada), and George Pess (Northwest Fisheries Science Center) and also featured field trips to the Penobscot River watershed and two poster sessions on Penobscot River Research and Diadromous Species Research in general.

Northern Maine Children's Water Festival

The Mitchell Center plays a key role in the Northern Maine Children's Water Festival that is held every two years at the University of Maine. Over 700 students and teachers from 14 middle and elementary schools all over northern Maine convened on campus on October 14, 2008 for the 8th biennial festival. The festival is a fun-filled way for students to learn 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. At the festival, water resource professionals from Maine and other parts of New England provide presentations and interactive displays about water, wetlands, human health and aquatic life.

This experience is provided at no cost to the participants, and the Festival budget includes funding to help schools pay for the cost of transportation to the University of Maine for the day. Festival attendance is limited, and schools are selected to attend on a competitive basis.

The Northern Maine Children's Water Festival is sponsored by the Maine Department of Environmental Protection, the Senator George J. Mitchell Center and Water Research Institute, Maine CDC Drinking Water Program, University of Maine Cooperative Extension and Conference Services, and Maine Sea Grant. Additional funding is provided by Efficiency Maine, Bangor Hydro, Brewer Water District, Verso Paper and Poland Spring.

Project WET

The Mitchell Center is working with the Maine Project WET coordinator and the northern Maine facilitator to increase awareness of Project WET across the state and provide regular educator training workshops. The Mitchell Center continues to provide communication and outreach support for Maine Project WET.

Conserving Significant Vernal Pools through Collaborative Local Initiatives

Basic Information

Title:	Conserving Significant Vernal Pools through Collaborative Local Initiatives
Project Number:	2009ME191B
Start Date:	3/1/2009
End Date:	2/29/2010
Funding Source:	104B
Congressional District:	2
Research Category:	Social Sciences
Focus Category:	Conservation, Ecology, Education
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publications

There are no publications.

Conserving Maine Vernal Pools through Collaborative Local Initiatives

2009 Maine Water Resources Research Institute Student Summer Award Report

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Problem

Vernal pools are small seasonal wetlands that fill with spring rains and typically dry down by summer's end. They are critical breeding habitat for species adapted to life in temporary waters, including fairy shrimp, spotted and blue-spotted salamanders, and wood frogs, and provide food to upland wildlife as well. Because of their small size and ephemeral nature, vernal pools are often overlooked by regulatory agencies and are commonly filled during development activities. As a result, vernal pools are among the most threatened of wetland types in the northeastern United States. In 2007, the Maine legislature recognized a subset of vernal pools (Significant Vernal Pools) as Significant Wildlife Habitat, a status that allows protection of both the pool and a portion of critical adjacent upland habitat. Pools that meet certain biological criteria are deemed to provide Significant Wildlife Habitat and as such are regulated under the Maine Natural Resource Protection Act. The State is unable to pre-map these resources, so it is incumbent upon private landowners to determine if they harbor Significant Vernal Pools prior to developing their land. Although regulation at the state level is a step in the right direction, the most efficient and cost-effective way to ensure the long-term viability of vernal pool resources is through local planning initiatives that move management from a reactive crisis mode to a proactive planning mode.

The viability of existing natural resources, including wetlands, is threatened by fragmentation that results from random development practices. Unplanned growth may compromise the quality of life reflected in Maine's motto, "the way life should be." Maintenance of rural character, along with economic development, can be achieved with proactive, town-level planning that includes natural resource assessments and development of ordinances or zoning practices that address connectivity of natural resources.

Objectives

- Guide 12 Maine towns through a pilot mapping and assessment process
- Develop training materials for towns and their citizen volunteers
- Produce, print, and distribute a *Maine Municipal Guide to Mapping and Conserving Vernal Pools* to additional Maine towns and land trusts
- Launch website *Community Based Conservation: Maine Vernal Pools* for disseminating information

The intention of this project is to work with community members and town officials, to inventory and assess vernal pool resources using trained citizen scientists, and to encourage towns to incorporate vernal pools into a natural resource database for conservation planning purposes. Given our limited resources, it became clear that our project should expand its purpose to include development of a *Maine Municipal Guide to Vernal Pool Mapping and Conservation Planning* designed to provide key scientific concepts behind the regulation and walk towns through the process of vernal pool mapping and planning from acquiring the appropriate scale aerial photographs to suggestions for storing, accessing, and using their data, and a website with supporting documents and materials to address landowner questions, assist town officials in their work, and train local volunteers.

Methodology

In response to the recent addition of Significant Vernal Pools to state-regulated Significant Wildlife Habitat, our initial proposal was to identify a single town within the Lower Penobscot watershed interested in wetland conservation that would engage with us in a community based approach to mapping their vernal pool resources. Evan Richert, the town planner in Orono, was interested in participating. In the 2 years following our initial conversations with Orono, this project grew to include a total of 12 towns currently engaged in various stages of this process. Extensive meetings and email contact with town officials lead to the establishment of a scope, strategy and project timeline. Coordination of this project consisted of guiding towns through the following steps:

1. Seek Community Support through Project Publicity
2. Acquire Aerial Photographs and Conduct Photo Interpretation
3. Identify Landowners with Potential Vernal Pool(s) on their Property and Secure Landowner Permission
4. Prepare Maps for Landowners and for Volunteers
5. Recruit Citizen Scientists (Volunteers)
6. Training Session 1 (Public Information)
7. Training Session 2 (Citizen Scientist Training)
8. Organize Data and Plan for Additional Field Visits
9. Submit Data to MDIFW
10. Update and Maintain Town Vernal Pool Database for Planning Purposes

Feedback pertaining to these steps from our town partners, State agencies including MDIFW, DEP, and SPO, and Maine Audubon, has served to guide the modification of project-related materials and development of new resources. As a recipient of the 2009 Water Resource Research Institute Student Grant Program, summer funding enabled me to obtain feedback from project partners and develop *The Maine Municipal Guide to Vernal Pool Mapping and Conservation Planning* (see attached Table of

Contents). In August we applied for and received full-funding ($13,300) from the Maine Outdoor Heritage Fund for the printing and distribution of this manual. Document review has been requested from our town partners, as well as individuals from the SPO, MDIFW, Maine Audubon, with an anticipated printing and distribution date of late January/early February.

Principal Findings and Significance

It is premature to reflect on the significance of this work before towns currently engaged have completed the process and before additional towns learn about and receive copies of our Manual. However, since the establishment of this pilot project, 8 additional Maine towns and numerous land trusts have requested assistance in this mapping and assessment process. Our website has seen over 1,200 hits since its launch date last April, and constituents from other Northeastern states and the province of New Brunswick have expressed interest in our work. Of the towns currently involved, most are preparing to conduct their second year of field assessments in the upcoming spring-time breeding season, and those that had planned to wrap things up after their second season last year, a committed to a third year in an effort to increase landowner permission to assess additional pools.

Citizen Science: Solving Groundwater Issues in New England

Basic Information

Title:	Citizen Science: Solving Groundwater Issues in New England
Project Number:	2009ME192B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Education, Groundwater, Water Quality
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publications

There are no publications.

Citizen Science: Solving Groundwater Issues in New England

1. Problem & Research Objectives:

Although the United States Environmental Protection Agency (USEPA) regulates public water systems, private drinking water wells are monitored by the landowner. Approximately 15% of Americans use private drinking water. This number increases to 20% in New England (USEPA 200). Without state and federal regulations, maintenance and testing does not always occur. Water quality is difficult to determine by sight, taste, or smell which makes testing critical. Some contaminants of concern include the following: microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides (USEPA 2008). Specifically, studies in New England have indicated the following contaminants: methyl-tertiary-butyl ether (MtBe), radon, and arsenic (USEPA 2008). There is a growing concern due to the combined force of potential contaminants, unknowing public, and lack of government regulations. Creating public outreach programs in one suggested solution to help alleviate the problems and educate the public.

The Groundwater Education through Water Evaluation & Testing (GET WET!) program (http://www.umaine.edu/WaterResearch/outreach/GETWET/index.htm) works with local students and the community to create a long-term groundwater quality database. The program travels to K-12 schools and 4-H clubs where students have collected their household private well water. After collection, students are taught to analyze the samples as a class project. Analysis is done with portable water chemistry test kits that include assays for the following: nitrates, hardness, chloride, pH, conductivity, and iron. Results from the analysis are added to the University of Maine's PEARL database (http://pearl.maine.edu/). PEARL is an online database created in the Senator George J. Mitchell Center. Researchers have gathered data from a variety of research projects, and the information is pooled to create an important historical record of Maine's environment and water resources. After adding their results to the database, students will complete the GET WET! program with a public presentation of their findings.

The current project's primary objectives have been to broaden citizen science research by investigating environmental education outcomes after implementing GET WET! in two different settings. The two settings include a formal (K-12 classroom) and an informal (4-H) environment in four different watersheds located across New England. Initial data has been collected through quantitative social science survey methodology. One overarching question has been to explore the differences between the formal and informal setting, and determine what factors influence the differences observed in outcomes (if any) of GET WET!. Some factors that have not been fully researched, but may be integral to the differences observed in the two settings are: life skills, classroom climate, interest, motivation, and science learner identity. Additionally, this investigation is addressing intergenerational knowledge transfer; the study of how parents and children influence each others' environmental knowledge, attitudes, and behaviors. Intergenerational knowledge transfer has the potential to not only influence the youth participants, but also their parents, household and community. However, there is little research that has fully delved into that potential. Therefore, this project will determine how intergenerational learning occurs between the students that participate in GET WET! and the parents of those students. The research will then further expand our understanding of intergenerational learning by creating a predictive model of parental behavior. This includes examining action competence and behavior change of the parents, as well as whether behavioral intention of the parents matches actual behavior. This will provide the information needed for researchers to utilize intergenerational knowledge transfer for environmental action, and allow students to act as catalysts for parents and communities. The predictive model of parental behavior will increase understanding of action competence, focus future programs on fostering intergenerational learning, and help remediate environmental problems of today and tomorrow.

Objectives

1. Investigate the factors that potentially influence private well water testing. These factors include health values, environmental values, and science learner identity.
2. Investigate current household behavior pertaining to well water use and general environmental behavior.
3. Research GET WET! participants knowledge related to water and the water cycle.
4. Compare differences in outcomes of GET WET! between formal (K-12 classroom) and informal (4-H) science education settings with life skills, classroom climate, interest, motivation, and science learner identity as potential factors influencing differences.
5. Explore intergenerational knowledge transfer about water resources between students after participating in GET WET! and their parents.
6. Predict household environmental behavior change after students participate in GET WET!

2. Methodology:

This research project will broaden existing citizen science literature and contribute to applied problem solving by investigating environmental education outcomes after implementing a groundwater quality curriculum, Groundwater Education Through Water Evaluation & Testing (GET WET!). Pre-GET WET! pilot testing (n=90) has been completed in four communities throughout New England. Quantitative social science survey methodology was used in a questionnaire provided to both students and their parents.

3. Principal Findings & Significance:

Our analyses indicate that 70% of our respondents use private well water in their household; 45% of our respondents that use private well water in their household have had a professional well water test; 11% of our respondents intend to test their well water in the next 6 months; and 53% of our respondents do not intend to test their well water in the next 6 months, and 36% responded with a maybe. Participants indicated detailed explanations for why they would not be testing their household well water in the next 6 months. The majority of those explanations fall within three categories including the following:

1. Taste, Color, Odor, and Contaminants
   - "Our water tastes great. I know of no local contaminants."
   - "If there is a change in color, odor, or taste"
   - "Only if the taste or there was a new odor"
   - "No change in our water- smell, color, no sickness"
   - "Because we could never get it there on time and tried to send it in 2 or 3 times. Our water also tastes clean and were not too worried"
   - "I know of no local contaminants"
2. Budget
   - "It would mostly depend on how it would impact our budget. We currently drink bottled water only."
   - "Not a priority. Not sure that anything is/would be wrong with it. Money a huge issue and no one really drinks the well water because it does taste weird and turns the white shower and sink orange"
3. No Change
   - "No reasons to indicate the need to have checked"
   - "We do not feel that there have been any changes since the last test was done."
   - "Nothing has changed, we're not ill-no particular reason to do so"
   - "I see no reason to"
   - "Unless I have reason to believe it has changed, I have no upcoming events to prompt me to test, or cause concern."
   - "Have no reason to think things have changed"
   - "No problem I am aware of. I built the house 15 years ago and never had the water tested. Deep well 525 ft in bedrock"
   - "No concerns"
   - "I believe my water is safe?"

Our analyses also indicate the following:

1. The majority of parents and students either somewhat agree or strongly agree that their water is safe. However, when compared to the parents (66), only approximately half as many students (32; of those that responded) strongly agree that their water is safe (Fig. 1).
2. The participants' (parents and students) responses were fairly ubiquitous across all categories when asked if they are worried about health risks from untreated water. Somewhat agree and strongly agree had the highest response rate for parents. Neither disagree nor agree and somewhat agree had the highest response rate for students (Fig. 2).

3. Participants' (parents and students) responses were fairly ubiquitous across all categories when asked if they thought compounds in their water may cause health problems. Neither disagree nor agree, somewhat agree, and strongly agree had the highest response rate for parents. Strongly disagree, neither disagree nor agree, and somewhat agree had the highest response rate for students (Fig. 3).
4. Parents mainly agreed that they were worried about property values if they found a well water problem with somewhat agree and strongly agree receiving the highest response rate (Fig. 4).
5. Parents responded to the following factors as the highest response rate to lowest response rate, respectively, that would prompt them to have a well water test: state or local requirement, contaminants in the area, change in odor of well water, change in color of well water, if a well testing program was available, if the neighbors well was contaminated, if unexplained health problems occurred, if they received a testing discount, if they received a testing reminder, and if there was a new baby in the household or visiting (Fig. 5).
6. Parents responses (66) were significantly high in favor (somewhat agree) of believing they would stop buying some products to save water. Somewhat agree also had the highest response rate for students (30), although approximately half of the parent's response (Fig. 6).
7. Neither disagree nor agree (28) and somewhat agree (26) received the highest response rates for parents when asked if they would give their own money to help the environment. Students also responded highest in neither disagree nor agree (21) and somewhat agree (23), although slightly lower responses than the parents (Figure 7).
8. Both parents and students responded with strongly agree or already do as their highest response rate when asked whether they would save water by using less water when they bathe (Fig. 8).
9. Both parents (44) and students (66) responded with already do as their highest response rate when asked whether they would save water by turning the water off when they brush their teeth (Fig. 9).
10. Somewhat agree (26) and strongly agree (28) received the highest response rate when parents were asked if they would save water by turning off the water while washing their hands. Somewhat agree (22) and already do (22) received the highest response rate when students were asked if they would save water by turning off the water while washing their hands (Fig. 10).
11. Students were asked if they would be willing to do the following actions to save water: write letters asking people to use less water, go from house to house to pass out environmental information, and go from house to house asking people to save water. The highest response rate for all three questions were given in strongly disagree, somewhat disagree, and neither disagree nor agree (Fig. 11).

4. Future Work:

Continue objectives 1, 2, & 3 in additional K-12 schools and 4-H clubs throughout New England (Spring 2010). Analyze objectives 5 & 6 from the Fall 2009 Pilot Study, and initiate and finalize objectives 4, 5, & 6 in K-12 schools and 4-H clubs throughout

New England (Spring 2010). Analysis and reporting of all objectives in Summer / Fall 2010.

5. Conference Proceedings:

Straub Crista L., Teresa Thornton, Jessica Leahy, John Peckenham, Laura Wilson, John Jemison, & Jean MacRae. 2009. A Pilot Study of Groundwater Quality Education Curriculum Using Private Well Water Testing. Northeast Private Well Water Symposium. Portland, Maine.

Straub Crista L., Teresa Thornton, Jessica Leahy, John Peckenham, Laura Wilson, John Jemison, & Jean MacRae. 2010. A Pilot Study: Human Dimensions of Private Well Testing. Maine Water Conference. Augusta, Maine.

Figure 1. The number of participants (parents and students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, or strongly agree that their water is safe.

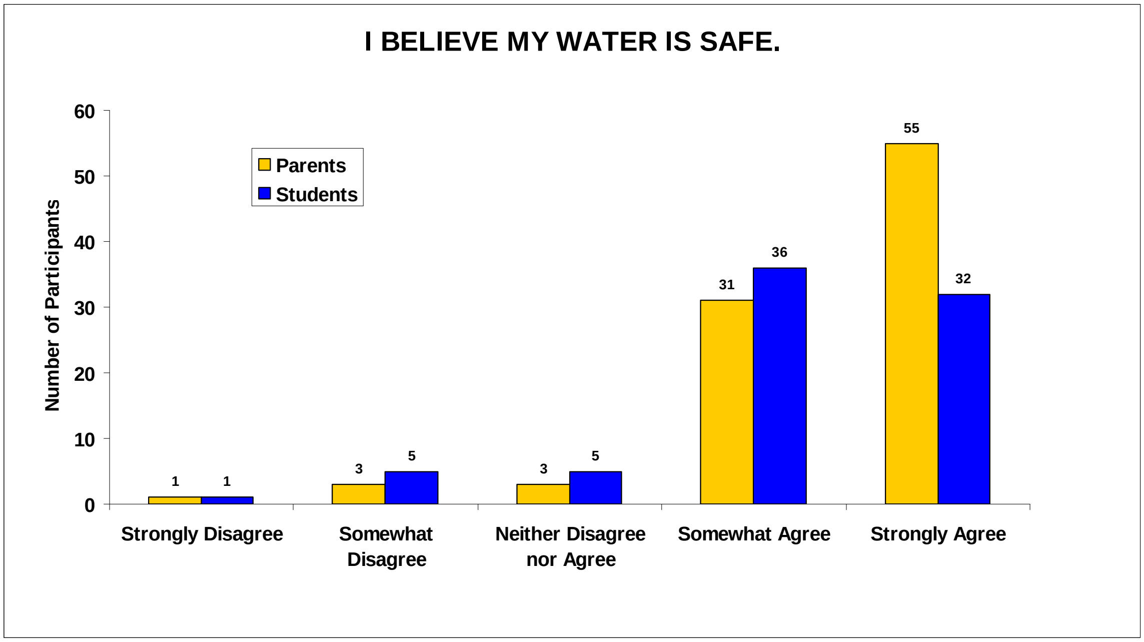


Figure 2. The number of participants (parents and students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, or strongly agree that they are worried about health risks from untreated water.

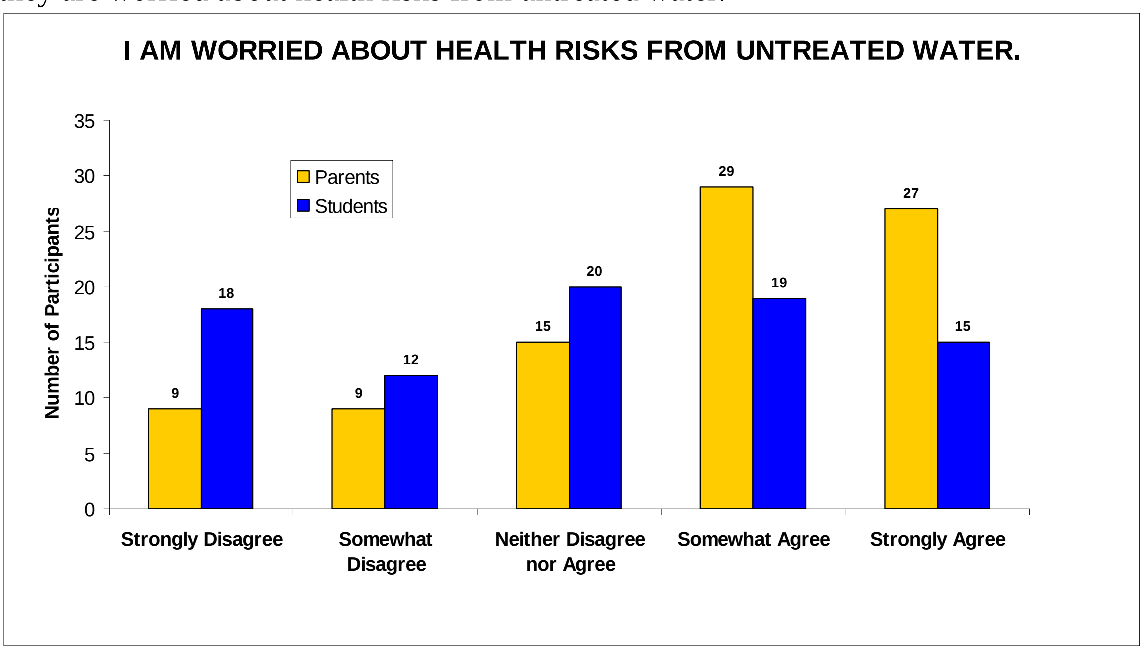


Figure 3. The number of participants (parents and students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, or strongly agree that there are compounds in their water that may cause health problems.

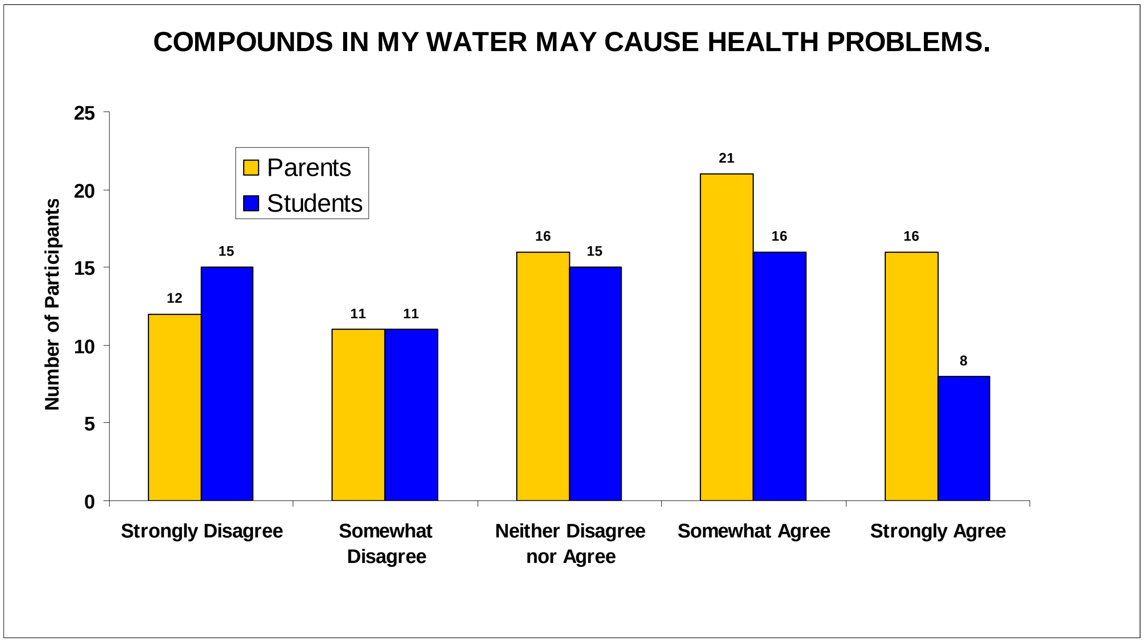


Figure 4. The number of participants (parents) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, strongly agree, or don't know if they are worried about their property values if they found a problem.

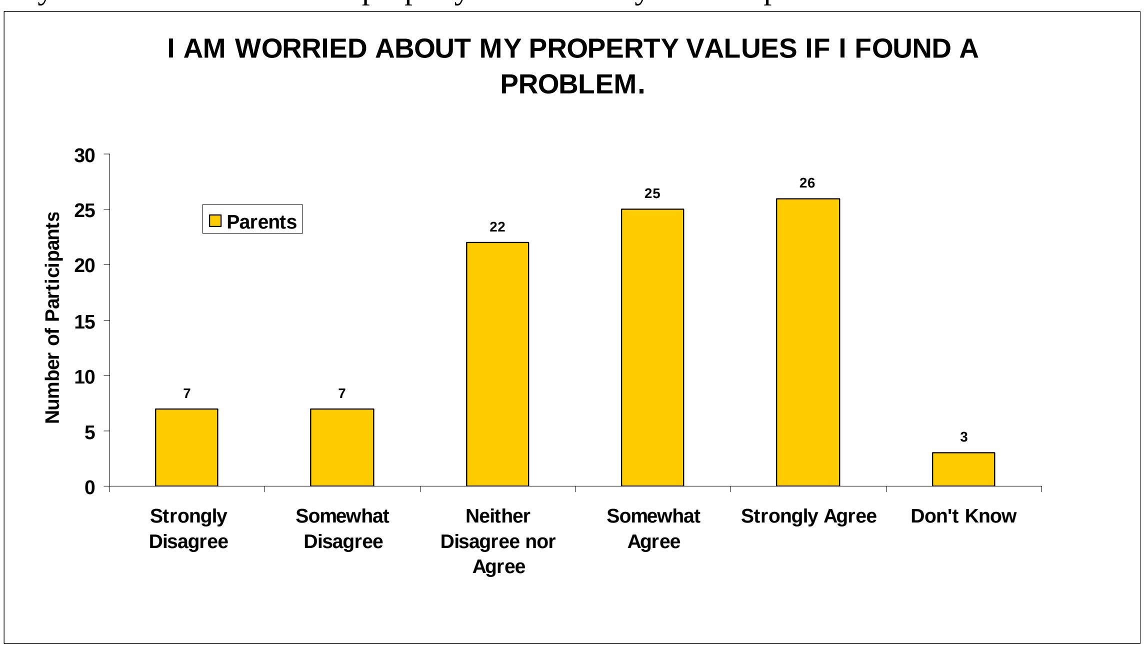


Figure 5. The number of participants (parents) that would consider specific factors to prompt them to have a well water test. The eleven factors were provided on the quantitative survey and are displayed as percentage replying yes in the figure (Fig. x).

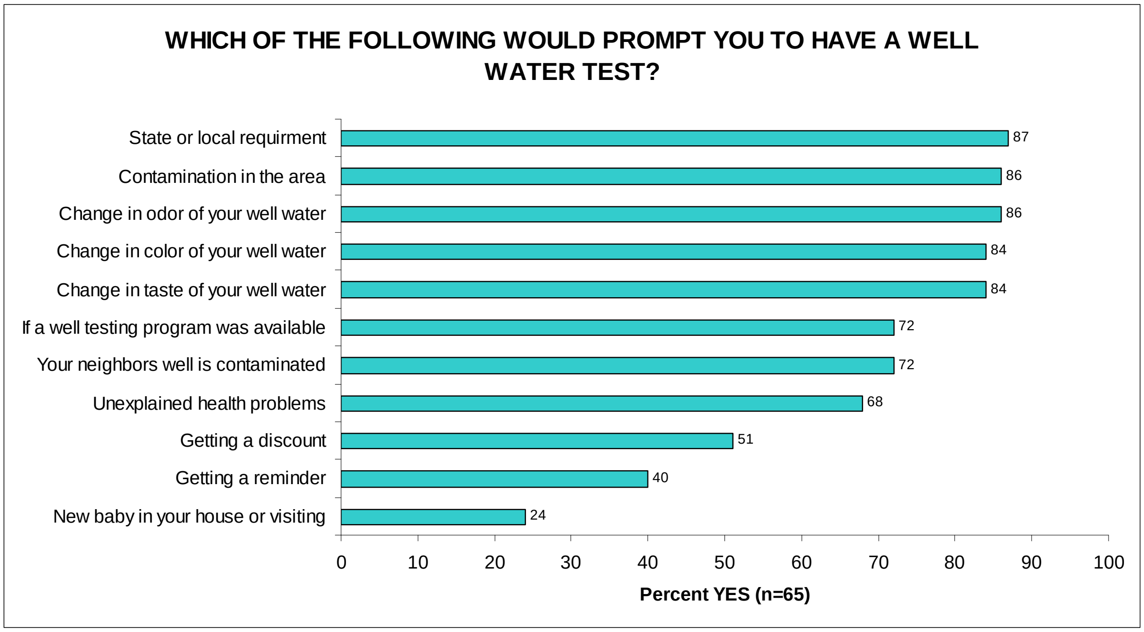


Figure 6. The number of participants (parents and students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, strongly agree, don't know, or already do believe they would stop buying some products to save water.

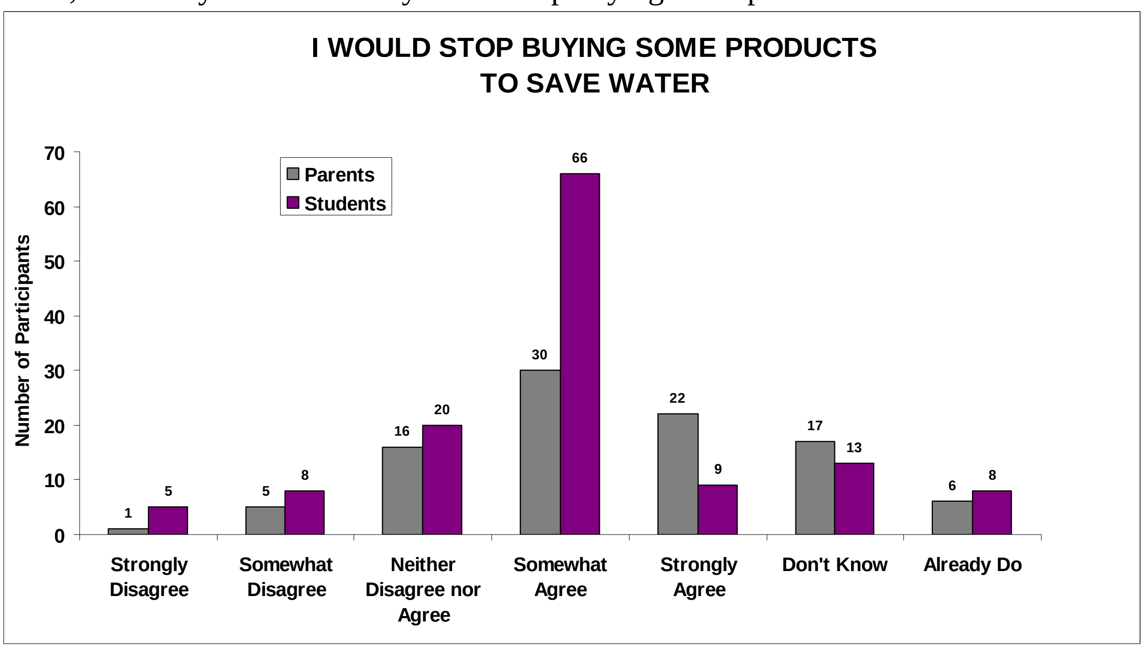


Figure 7. The number of participants (parents and students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, strongly agree, don't know, or already do believe they would give their own money to help the environment.

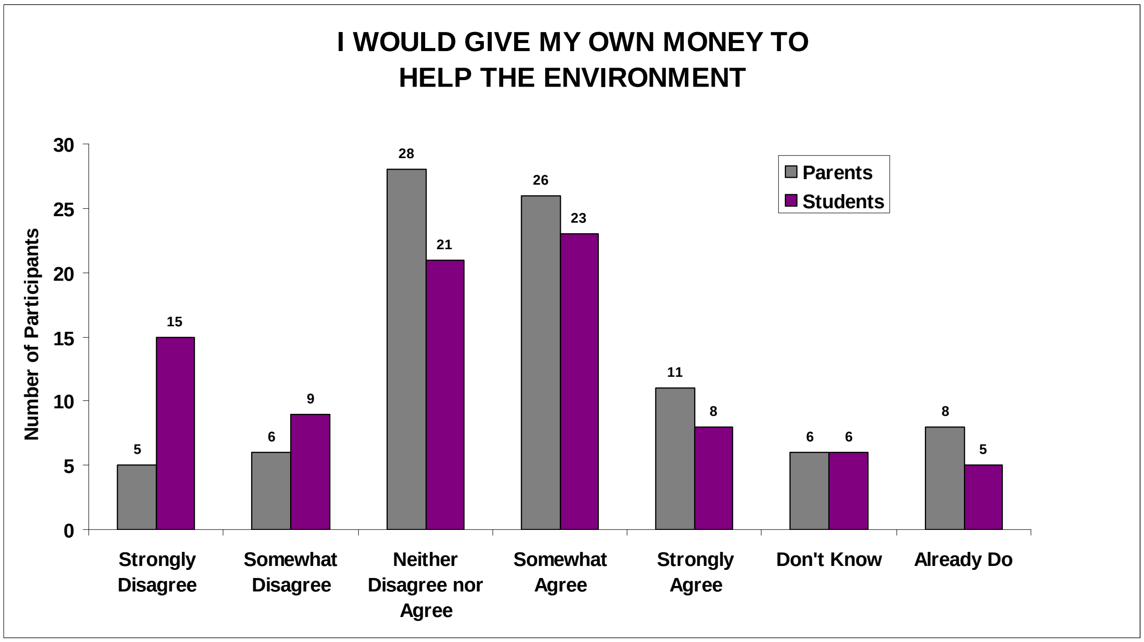


Figure 8. The number of participants (parents and students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, strongly agree, don't know, or already do believe they would save water by using less water when they bathe.

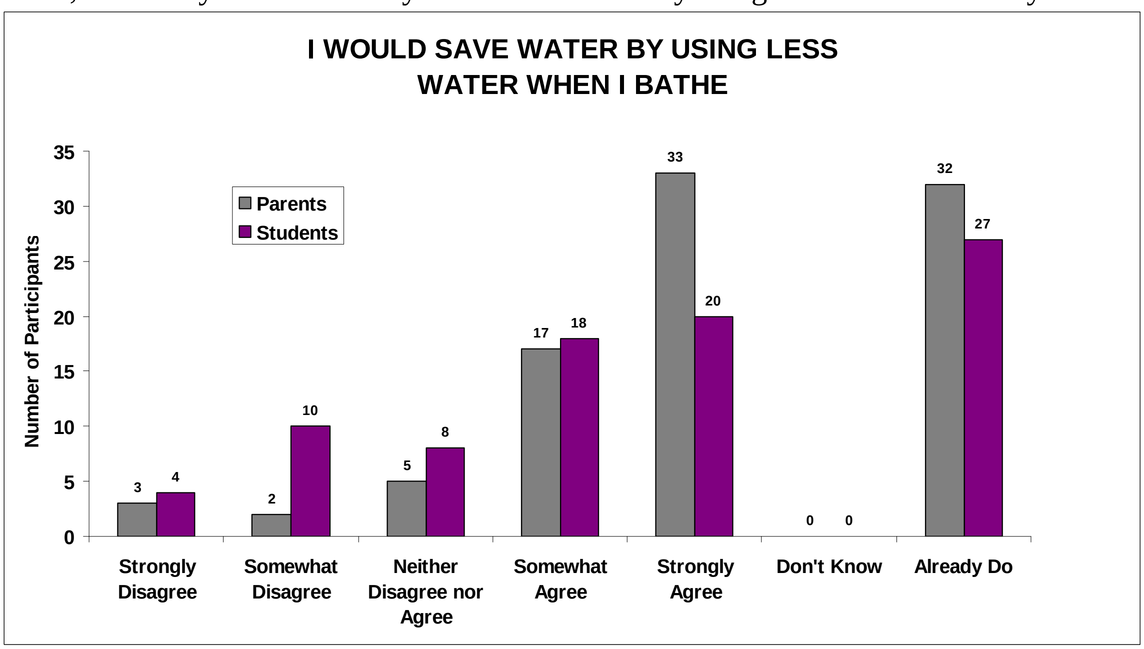


Figure 9. The number of participants (parents and students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, strongly agree, don't know, or already do believe they would save water by turning the water off when they brush their teeth.

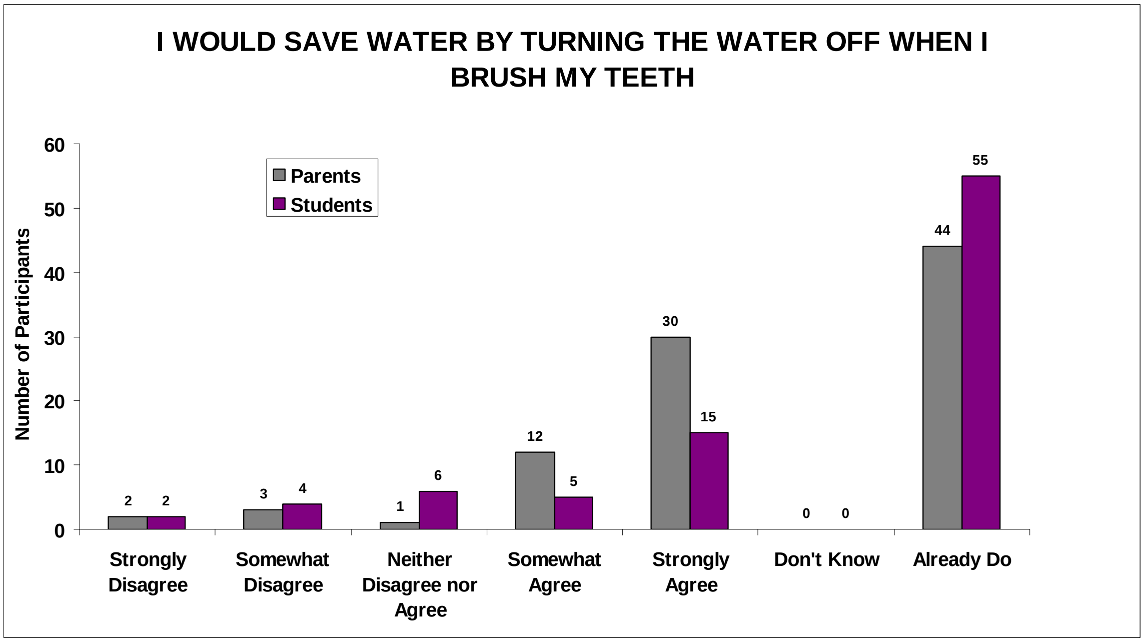


Figure 10. The number of participants (parents and students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, strongly agree, don't know, or already do believe they would save water by turning the water off while they wash their hands.

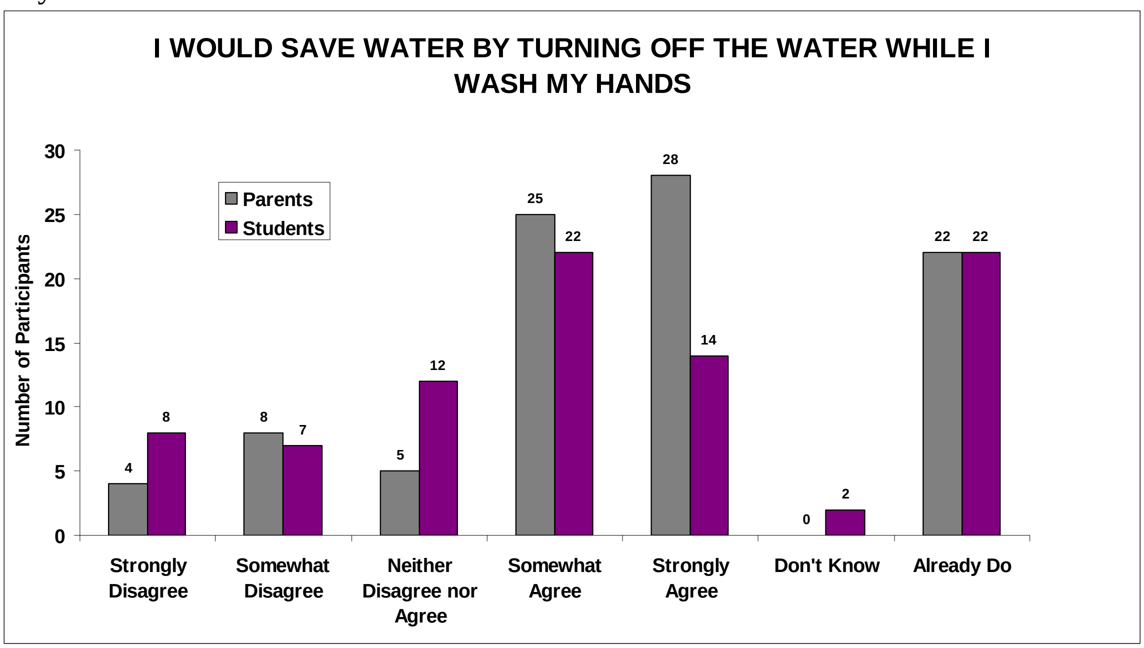
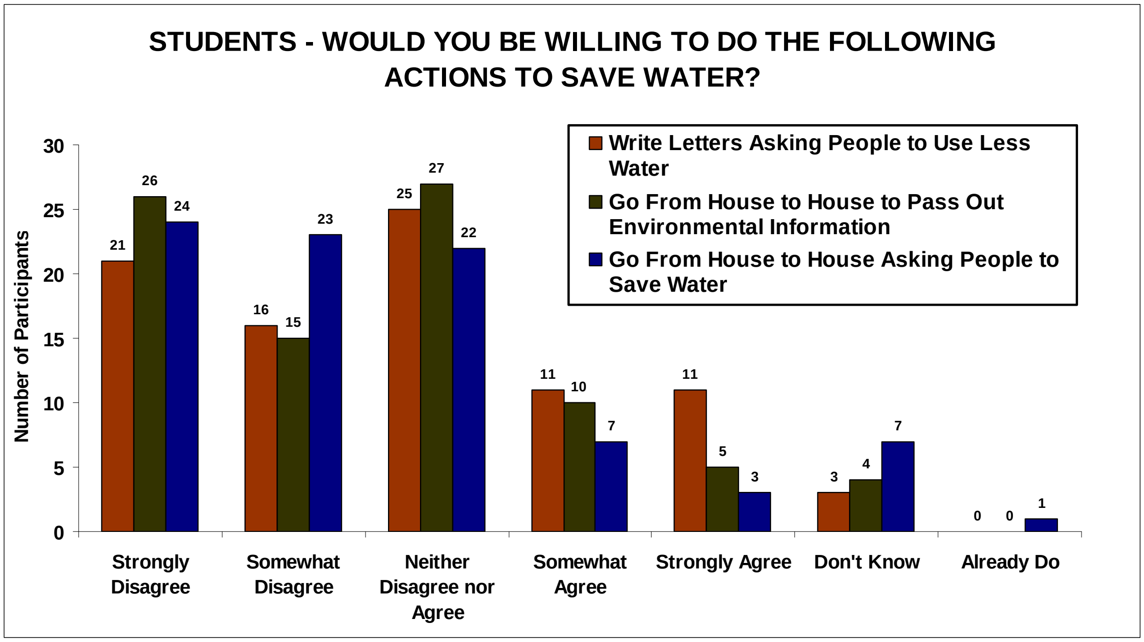


Figure 11. The number of participants (students) that either strongly disagree, somewhat disagree, neither disagree nor agree, somewhat agree, strongly agree, don't know, or already do believe they would be willing to do the following actions to save water: write letters asking people to use less water, go from house to house to pass out environmental information, and / or go from house to house asking people to save water.



USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	0	5
Masters	10	0	0	0	10
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	17	0	0	0	17

Notable Awards and Achievements

Maine's Sustainability Solutions Initiative

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 (SSI), a partnership between the University of Maine, University of Southern Maine and other institutions of higher education.

Producing knowledge and linking it to actions that meet human needs while preserving the planet s life-support systems is emerging as the most fundamental and difficult challenge for science in the 21st century. There is growing consensus that traditional methods of generating and using knowledge must be fundamentally reorganized to confront the breadth, magnitude, and urgency of many problems now facing society. SSI seeks to transform Maine s capacity for addressing these scientific challenges in ways that directly benefit Maine and other regions. The program of research will also help Maine increase economic activity and technological innovation in ways that sustain the State s remarkable quality of place .

Building Teams & Partnerships
Solving sustainability problems requires unprecedented levels of program integration involving a high degree of interdisciplinary teamwork and robust university-stakeholder partnerships. Our strategy for strengthening sustainability science and practice has two major components. First, all SSI research teams include experts in the social, economic, and ecological dimensions of sustainability challenges as well as researchers skilled in linking knowledge to action (e.g., experts in communication, political science, public policy). Second, these interdisciplinary teams work in close partnership with stakeholders to maximize the relevance and potential value of research for decision-making. Our collaborative approach rests on a foundation of mutual respect, open communication, and a belief in the value of diverse ideas and experiences.

Understanding Landscape Change
Initially, SSI will focus on understanding three pressing drivers of landscape change urbanization, forest ecosystem management, and climate change. Landscape change has not only been identified as one of the grand challenges in the environmental sciences by the National Research Council, it is also a central concern in recent reports focusing on the future of Maine s economy and way of life. For example, portions of southern Maine are experiencing rapid sprawl while record sales of private forest lands and mill closures are transforming the social and economic fabric of northern and western Maine. In addition, climate change will likely alter the composition and function of forests, influencing their ability to meet traditional markets as well as potential new markets (e.g., carbon sequestration and bioproducts). Our ultimate goal is to build SSI s capacity for generating solutions to an array of problems in and beyond Maine (e.g. renewable energy, alternative transportation).

Water Resource-Related SSI Projects
The following funded projects provide direct linkages with the Maine WRRI program. Opportunities for further collaborations that enhance both research programs will be actively pursued in the future.

- Linking Knowledge with Action: Refining Maine's Mercury Fish Consumption Advisory
  Team Leader: Aria Amirbahman, Civil & Env. Engineering, University of Maine
- Protecting Natural Resources at the Community Scale: Using population persistence of vernal pool fauna as a model system to study urbanization, climate change and forest management
  Team Leader: Aram Calhoun, Wildlife Ecology, University of Maine
- Decision tools to support water resources sustainability of managed lake systems
  Team Leader: Shaleen Jain, Civil & Env. Engineering & Climate Change Institute, UMaine

- Adaptation Strategies in a Changing Climate: Maine's Coastal Communities and the Statewide Stakeholder Process
  Team Leader: Shaleen Jain, Civil & Env. Engineering & Climate Change Institute, UMaine
- Analysis of Alternative Futures in the Maine Landscape using Spatial Models of Coupled Social and Ecological Systems
  Team leader: Rob Lilieholm, Forest Resources
- Sustaining and Restoring Urban Stream Resources in Maine
  Team leader: Dave Owen, School of Law, University of Southern Maine
- Researching Knowledge-to-Action Linkages to Promote Stakeholder and Community Engagement
  Team leaders: Laura Lindenfeld, Communication and Linda Silka, Margaret Chase Smith Center for Public Policy