Senator George J. Mitchell Center for Environmental & Watershed Research
Annual Technical Report
FY 2006

Introduction

Maine Water Resources Research Institute FY06

The Maine Water Resources Research Institute serves an important function in the state through its support of research, graduate studies, and outreach. During the past year the Maine Institute has supported five projects: Valuing Environmental Changes for Decision Making in Dam Removal; Developing a Sequential Time-Weighted Monitoring Approach for Pesticides in Rivers; Developing a New Method to Identify Disinfection By-Products in Drinking Water; and A Study of Food-Web Structure, Landscapes, and Lake Nutrient Enrichment. Additionally, one specific Information Transfer project was supported: Enhancing Lakefront Buffer Adoption through Social Marketing. These projects alone provided support to four graduate students and four undergraduate students.

Institute Director, John Peckenham, stepped down in 2006 as the Interim Director of the Senator George J. Mitchell Center for Environmental and Watershed Research. The Mitchell Center provides the administrative home for the Institute. In June 2006, David Hart became the new Director of the Mitchell Center. David brings an extensive background in aquatic systems ecology that complements existing expertise on campus. This change will greatly enhance our efforts to have the Maine Institute increase the breadth and accessibility of water research in Maine.

This year the highly successful Maine Water Conference was held in March with a new format to allow for more presentations. 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. We take great pride in being able to address many of the important water issues in Maine and bring together diverse interest groups.

The Water Resources Research Institute 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 FY06, the Maine Institute had projects funded by state agencies (Department of Inland Fish and Wildlife, Department of Environmental Protection, Maine Drinking Water Program), federal agencies (Department of Agriculture, Environmental Protection 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

The Maine Water Resources Research Institutes supports research and information transfer projects using 104b funds. Projects are awarded on a competitive basis using a multiple screening process. The Research Advisory Committee, comprised of the Institute Director, Regional U.S.G.S. Chief Scientist, State and Federal Agencies representatives, and Professionals, set the research priorities based on current state needs and issues. The Institute issues a call for pre-proposals. 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.

Evaluating scope and trends for decreasing base cations (and increasing diluteness)

Basic Information

Title:	Evaluating scope and trends for decreasing base cations (and increasing diluteness)
Project Number:	2004ME27B
Start Date:	4/1/2004
End Date:	3/31/2006
Funding Source:	104B
Congressional District:	2
Research Category:	None
Focus Category:	Acid Deposition, Climatological Processes, Surface Water
Descriptors:	None
Principal Investigators:	Steve Kahl, Katherine Webster, Ivan Fernandez

Publication

1. Rosfjord, C., J.S. Kahl, K. Webster, C. Loftin, S. Nelson, 2004. Poster: A 20-Year Re-evaluation of Trends in a Statistical Population of Lakes in the Northeastern U.S. Maine Water Conference, Augusta, ME, April 2004.
2. Rosfjord, C., J.S. Kahl, K. Webster, C. Loftin, S. Nelson, 2004. Poster: A 20-Year Re-evaluation of Trends in a Statistical Population of Lakes in the Northeastern U.S. Graduate Student Expo, University of Maine, Orono, ME, April 2004.
3. Rosfjord, C. 2005. An Evaluation of 20 Year Changes in Chemistry in the EPA Eastern Lake Survey, a Statistical Population of Lakes in the Northeastern U.S. M.S. Thesis. University of Maine

Abstract

In 1984, the Environmental Protection Agency conducted the Eastern Lake Survey (ELS-I) to assess the overall status of lakes in the east, with particular attention to the relationship between acid deposition and pH. In 1986, a statistical subset of the ELSI lakes, consisting of 145 lakes in the northeast, was re-sampled for ELS-II. Since the 1986 sampling, the Clean Air Act Amendment (CAAA) of 1990 resulted in reductions in sulfate emissions. The goal was to improve the biologically relevant chemistry of surface waters. In 2004, we re-sampled the 145 Northeastern lakes on the 20th anniversary of their original sampling. The data produced by the 2004 re-sampling allow for assessments of biologically relevant chemical trends in a wide range of lakes. Of particular interest are trends in base cation concentrations, the by-products of weathering reactions that produce acid neutralizing capacity (ANC) of surface waters and buffer against acid inputs. The lack of response of surface water pH to increase despite declines in acid deposition has been attributed to a concurrent decline in surface water base cation. Our objectives are to address long-term chemical trends in a wider chemical range of lakes while enhancing the statistical coverage of the northeastern region by using the ELSII sub-population. Trends in base cations have largely been studied in the most sensitive low ANC (<25 µeq/L) waters with few anthropogenic influences outside of atmospheric deposition. Chemical trends in high ANC lakes (>100 µeq/L) with greater anthropogenic influences are poorly understood. This research found base cation concentrations declined in a wide range of ANC waters in remote lakes in the northeast. However, lakes affected by road salt have generally experienced increases in base cation concentrations over the past 20 years. This information will allow for assessment of the CAAA and its effectiveness in increasing pH in surface waters through reductions in sulfate emissions. Additionally, this research has important implications for designing future assessments of changes in water chemistry resulting from changes in emissions.

Summary

In response to the Clean Air Act Amendments of 1990, decreases in emission of sulfur dioxide have lead to decreases in deposition of sulfate and subsequent decreases in surface water concentrations of sulfate. In the ELS-II population, sulfate decreased in over 90% of the population with an average decrease from 110.8 µeq/L in 1984 to 85.9 µeq/L in 2004. Regionally there were some differences in declines in sulfate, with the greatest decreases in the Adirondacks and the smallest decreases in Maine. Nitrate also decreased in approximately 75% of the population with average decreases from 1.94 µeq/L in 1984 to 1.13 µeq/L in 2004.

Base cations Ca and Mg showed considerable variation between lakes affected by road salt and lakes unaffected by road salt. In the high Cl population, over 85% of the lakes increased in Ca and Mg with an average increase of +62.30 µeq/L/20yr. In the low Cl group, over 70% of the lakes experienced decreases in Ca and Mg with an average decrease of -6.89 µeq/L/20yr Ca+Mg. For the purposes of this paper, it is assumed that high Cl lakes do not represent changes in lake chemistry resulting from changes in atmospheric deposition. Ca and Mg also showed variation between ANC classes. Within the low Cl group, lakes in the lower ANC classes showed greater decreases in Ca+Mg than did lakes in the higher ANC class.

Despite average decreases in Ca+Mg in low Cl lakes, there were average increases in ANC in low Cl lakes, indicating the importance of declines in sulfate to ANC. Nearly 90% of the ANC class I/low Cl lakes experienced increases in ANC over the 20 years with an average increase from -1.66 µeq/L ANC in 1984 to 7.82 µeq/L ANC in 2004. Approximately 80% of the ANC class II/low Cl experienced increases in ANC with an average increase from 61.99 µeq/L in 1984 to 68.70 µeq/L in 2004.

Nearly 80% of the ANC class I in the low Cl group experienced increases in EqpH with an average change of +0.25 pH units/20yr. This brought the average EqpH for ANC class I/low Cl from 5.56 in 1984 to 5.81 in 2004. There were, however, average decreases in EqpH for ANC class II and class III.

Concentrations of total aluminum decreased in approximately 90% of the population. Changes in total Al differ by ANC class, with ANC class I experiencing the greatest average decrease in total Al of -73.64 µg/L/20yr.

Approximately 86% of the population experienced increases in DOC with an average increase of +1.51 mg/L from 4.05 mg/L in 1984 to 5.56 mg/L in 2004. There are regional differences in changes in DOC. Maine experienced the greatest increase in DOC out of the 5 regions with an average increase from 4.46 mg/L in 1984 to 6.94 mg/L in 2004.

These 20 year trends are summarized in Fig. 5.22, 5.23, and 5.24.

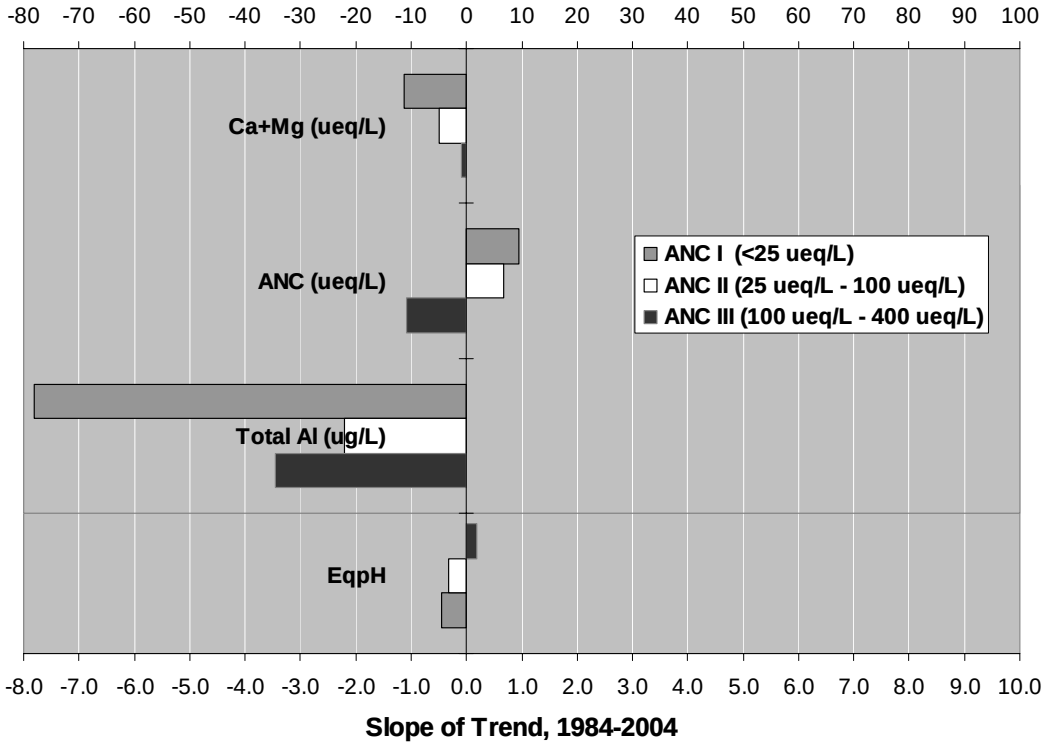

Figure 22. Average trends in the low chloride group, 1984-2004.

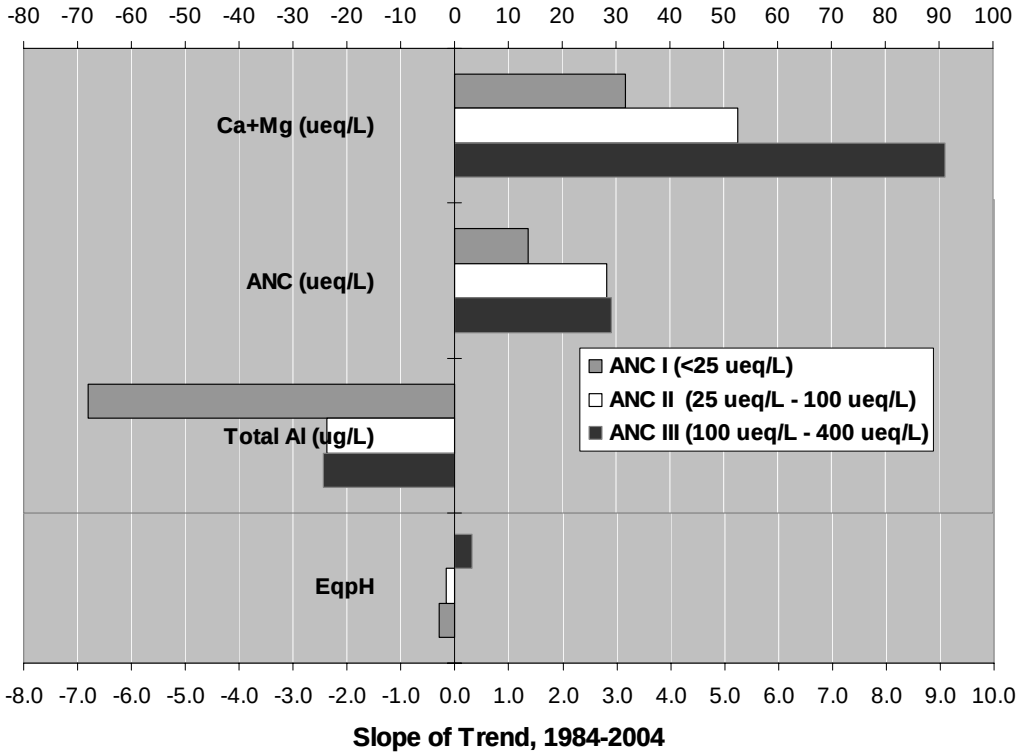

Figure 23. Average trends in the high chloride group, 1984-2004.

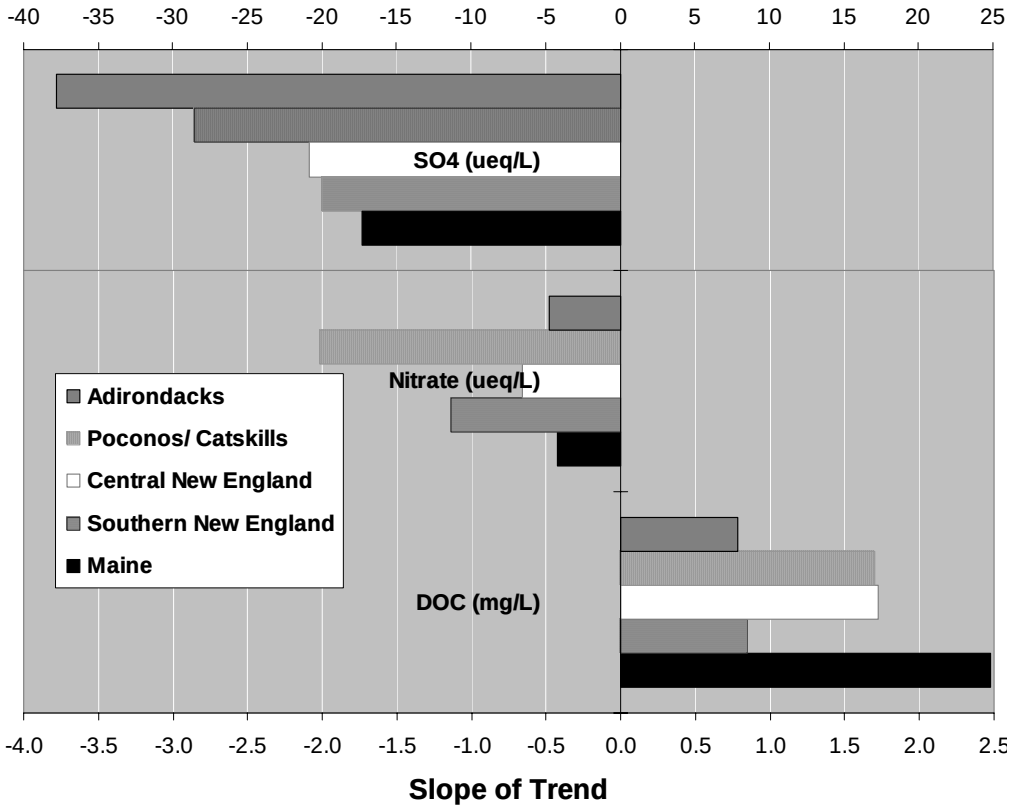

Figure 24. Regional trends in sulfate (µeq/L), nitrate (µeq/L) and DOC (mg/L), 1984-2004

Conclusions

Many of these trends indicate recovery from acid deposition and the success of the Clean Air Act Amendments. Decreases in emissions of sulfur dioxide due to the passage of the CAAA have clearly resulted in decreases in sulfate concentrations in surface waters. Decreases in the acid anion sulfate have resulted in an increase in ANC and an increase in pH, particularly in low ANC systems. Both ANC and pH are indicators of biological conditions and increases in these parameters indicate potential biological recovery in the most sensitive surface waters. Additionally, total Al had considerable decreases,

especially in low ANC lakes. Due to the toxic affects of Al on gilled organisms, decreases in total Al is an important indicator of recovery from acid deposition.

However, there are some trends which indicate that recovery from acid deposition may take longer than expected. Decreases in the base cations Ca+Mg, particularly in low ANC lakes, result in a diminished ability of surface waters to neutralize acid inputs. It is likely that increases in ANC over the 20 years would be more considerable had base cations not decreased during this time. Furthermore, due to increases in DOC, there are additional sources of acidity in many northeastern lakes.

Regionally, the Adirondacks appear to be making the greatest headway in recovery. The Adirondack region has the greatest average decrease in sulfate, the greatest average increase in EqpH, and the greatest average decrease in total Al. Conversely, Maine has the smallest average decrease in sulfate, the smallest average increase in ANC, the greatest average decrease in EqpH, and the smallest average decrease in total Al. Interestingly, the Adirondack region has the greatest average decrease in Ca+Mg while Maine has the greatest average increase in Ca+Mg. This indicates that while base cation may contribute to the acid neutralizing capacity of surface waters, changes in base cation concentrations are not driving recovery in northeastern suface waters.

The prevalence of road salt in northeastern surface waters proved to be a confounding factor when analyzing the effects of the CAAA on surface waters. The majority of the lakes in this study (56%), were affected by elevated concentrations of Cl, presumably

from road salt. While Ca+Mg had average decreases in low Cl lakes, 85% of the high Cl lakes experienced average increases in Ca+Mg.

Nutrient cycling within the Meduxnekeag River and the use of periphytic algae as an indicator of nutrient loading

Basic Information

Title:	Nutrient cycling within the Meduxnekeag River and the use of periphytic algae as an indicator of nutrient loading
Project Number:	2004ME31B
Start Date:	4/1/2004
End Date:	3/31/2006
Funding Source:	104B
Congressional District:	2
Research Category:	None
Focus Category:	Agriculture, Management and Planning, Non Point Pollution
Descriptors:	None
Principal Investigators:	Bryan Dail, Steve Kahl, Katherine Webster

Publication

1. Fretwell, L., D.B. Dail, K.E. Webster, and S.H. Brawley. The relationship between phosphorus and nitrogen concentrations, algal growth, and land use in the Meduxnekeag River watershed. Poster presented at the 2005 Graduate Student Research Exposition, April 11-12, 2005. Orono, Maine.
2. Fretwell, L., D.B. Dail, K.E. Webster, and S.H. Brawley. The relationship between phosphorus and nitrogen concentrations, algal growth, and land use in the Meduxnekeag River watershed. Poster presented at the 2005 Maine Water Conference, March 22, 2005. Augusta, Maine.
3. Fretwell, L., D.B. Dail, K.E. Webster, J.S. Kahl, S.H. Brawley, and L. Wilson. Periphytic algae as an indicator of nutrient loading to the Meduxnekeag River. Poster presented at the 2004 Maine Water Conference, April 21, 2004. Augusta, Maine.
4. Fretwell, L., D.B. Dail, K.E. Webster, J.S. Kahl, S.H. Brawley, and L. Wilson. Periphytic algae as an indicator of nutrient loading to the Meduxnekeag River. Poster presented at the 2004 Graduate Student Research Exposition, April 12-13, 2004. Orono, Maine.
5. Fretwell, E., 2006. The Temporal and Spatial Relationship Between Phosphorus and Nitrogen Concentrations, Algal Growth, and Nutrient Sources in the Meduxnekeag River Watershed. M.S. Thesis. University of Maine.

Progress Report 2004

Nutrient cycling within the Meduxnekeag River and the use of periphytic algae as an indicator of nutrient loading

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Lisa Fretwell	**Masters Candidate, Ecology and Environmental Sciences Program**

Period covered by this report: April 2004-April 2005

ABSTRACT

A 20-mile segment of the Meduxnekeag River in Aroostook County, Maine, that traverses Houlton Band of Maliseet Indian (HBMI) tribal lands is experiencing substantial filamentous algal blooms in summer months. The algal blooms have lowered dissolved oxygen (DO) levels in the river to the extent that a 6-mile stretch within the segment has been deemed "impaired" by the Department of Environment Protection (DEP).

Water chemistry data collected by the HBMI are available from 1995 to the present for this stretch of the river and indicate that the blooms may be phosphorus (P) limited, but that the algae are moderating stream chemistry and responding to flow dynamics to an extent that controls over algal production are unclear. A Watershed Protection Plan/Environmental Assessment for the Main Branch of the Meduxnekeag River was published in 1993, a Total Maximum Daily Load (TMDL) Report was published by the Department of Environmental Protection (DEP) in 2000, and the U.S. Geological Survey (USGS) is finalizing a sediment study it conducted this summer (2003).

Currently, no research has linked the existing water quality data to nutrient dynamics in the river, or pinpointed the relative input contributions from point and non-point sources, of which there are many. These including unbuffered agricultural stream inputs, wetland, and lake recharge as well as industrial and wastewater effluent and proximity to impermeable surface inputs; all of these inputs are upstream of the Maliseet tribal lands. We proposed to evaluate the underlying cause of the eutrophication by compiling and analyzing the existing data, investigating nutrient cycling in the river (including sediment and the water column), identifying nutrient loading areas and relative contributions of point and non-point sources, and determining temporal and spatial changes in the algae. Our overarching goal is to identify the causes of the problem, or to prioritize the likely causes, and thus provide supportive data that may lead to recommendations for remedy.

State Water Quality Problem and Research Objectives

Although environmental regulations have drastically reduced point source pollution, non-point source pollution remains a leading cause of water quality problems nationwide. State inventories indicate that agriculture impacts 48 percent of impaired rivers and streams (EPA, 2002). One of the major constituents of non-point source pollution is sediment, which is transported from agricultural and urban areas and carries heavy metals, pesticides, oils, and nutrients. High nutrient concentrations are a leading cause of impairment and eutrophication, a symptom of which is oxygen-depleting algal blooms.

The algal blooms in the Meduxnekeag River depress dissolved oxygen (DO) levels and alter the habitat of fish and other biota. Throughout the state, rivers are being altered to such an extent that they are losing native fish populations. Tribal members have observed non-native fish (bass, sucker, pickerel) becoming dominant while native trout numbers are declining (Ellis, pers. comm. 2003). The Maine State Planning Office's River Study lists the Meduxnekeag River as having natural and recreational values of statewide significance. However, the algal blooms and resulting low DO levels are threatening this status. A 6-mile segment of the river downstream of Houlton is listed on the state's 303d and 305b list for non-attainment of water quality standards because of high nutrient loads and low DO levels.

Although its presence on the impaired list legally requires corrective measures to be taken, so little is known about nutrient sources and cycling in the Meduxnekeag River that the any solution would be speculative at this point in time. Moreover, an evaluation of the Meduxnekeag River eutrophication, which is rare for Maine, will be useful for our understanding of processes statewide, because of increasing pressures on many Maine waters. Also, since the project will quantify the relative inputs from point and non-point sources, our research will be applicable to other areas with non-quantified point and non-point sources of nutrient enrichment.

Several states are battling eutrophication problems that became widespread before they were well understood, forcing a reactive approach; Maine, on the other hand, has an opportunity to be proactive and address the issue while it is still relatively small scale. We can gain an understanding of nutrient cycling in the river and use that knowledge to drive a restoration plan that will be a model for other areas of the state and beyond.

Research Goal:

To determine the spatial and temporal relationships between nutrients, algal growth, and land use in the Meduxnekeag River corridor?

This goal is bring addressed by three general research objectives:

1) **What are the spatial and temporal phosphorus and nitrogen trends in the Meduxnekeag River, and how do they correlate to nutrient sources in the watershed?**

2) **Are spatial and temporal patterns in the algal growth an indicator of nutrient concentrations?**

3) **Do the water column and algae have unique δ15N stable isotope signatures that we can relate to specific point source and non-point source nutrient sources within the watershed?**

METHODS

The watershed will be divided into three zones as shown in the conceptual model below (Fig. 1). Zone 1 will extend from the headwaters at Meduxnekeag Lake to just upstream of AE Staley's (a starch plant) and contains predominantly agricultural land. Zone 2 contains AE Staley's, the confluence with the South Branch of the Meduxnekeag River, and downtown Houlton. Zone 3 contains the WWTP and HBMI tribal lands.

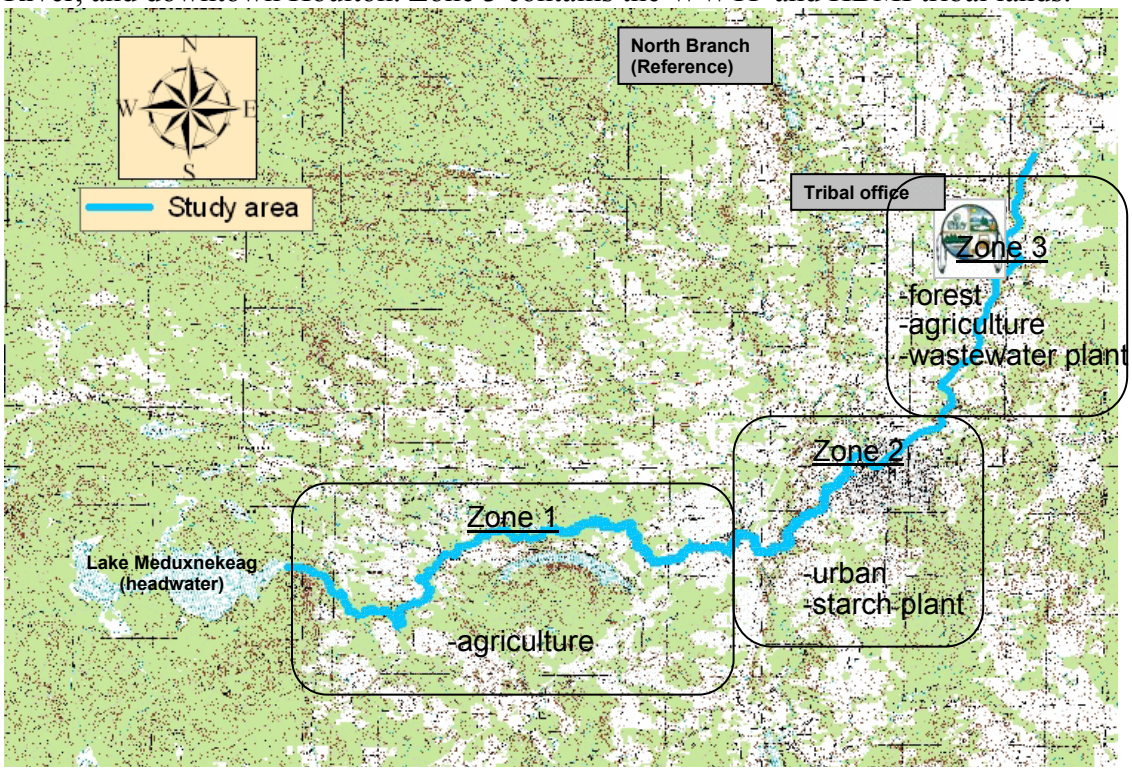


Fig. 1 Conceptual diagram of the Meduxnekeag Study Reach.

We compiled and analyzed existing data, and determine gaps in sampling regimes as they fit within the general framework of the conceptual river chemistry influences in Fig 1. We then devised a detailed sampling plan for the Spring of 2004 which added a substantial number of sampling areas to those already analyzed on a regular basis by the Maliseet Tribe's water quality specialists.

Assessing water chemistry and Algal cover patterns

At each sampling area along the 20 mile reach, we established permanent bank markers to delineate a water sampling plan and an algal assessment plan. The basic features of the water chemistry and algal assessment plan are shown in Fig. 2. Nutrient sampling and algal assessments were performed biweekly from May through September and algal grab samples for identification and natural abundance isotope forensics were obtained twice.

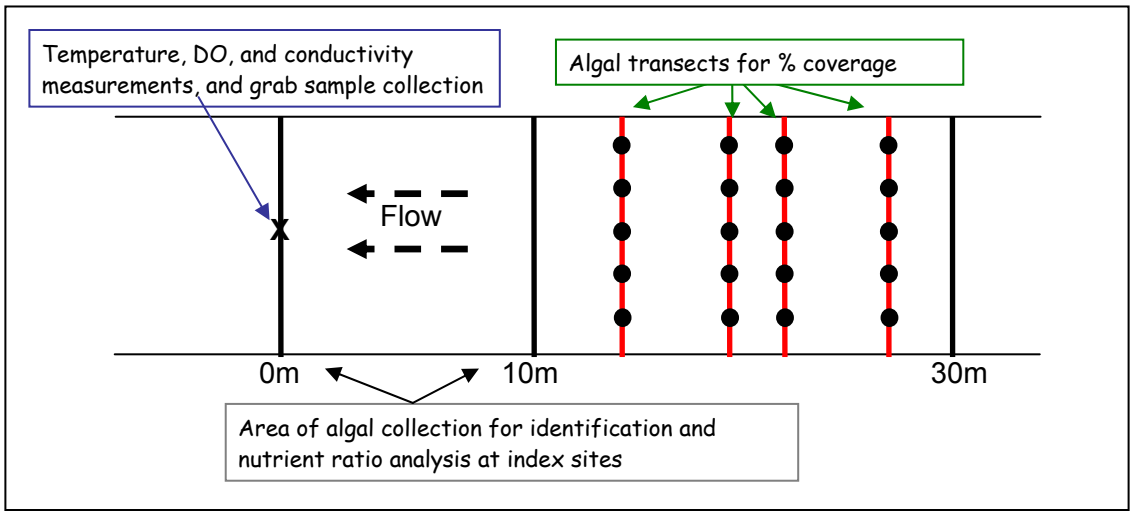


Fig 2. Conceptual diagram of the water chemistry sampling plan and the algal assessment transects.

PRINCIPLE FINDINGS TO DATE

Water chemistry

Soluble reactive phosphorus, that P which is most available for plant and microbial uptake, was often not differentiable from the detection limits of our method, therefore we report the season average of Total P which includes soluble and particulate P in unfiltered samples (Fig. 3). Season averages for the individual sites necessarily have a considerable amount of error associated with them and this is owing to processes in the watershed that mobilize P as well as the water flow regime. However, we do see a trend in increasing P loading as one goes from headwaters to the furthest point downstream in our study (Fig. 3). Total P levels appear to have a high value just downstream of the waste water treatment plant and the large error is consistent with a discreet treated water release pattern.

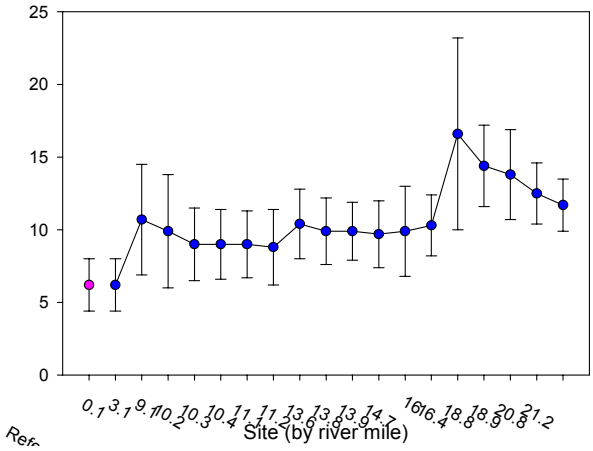
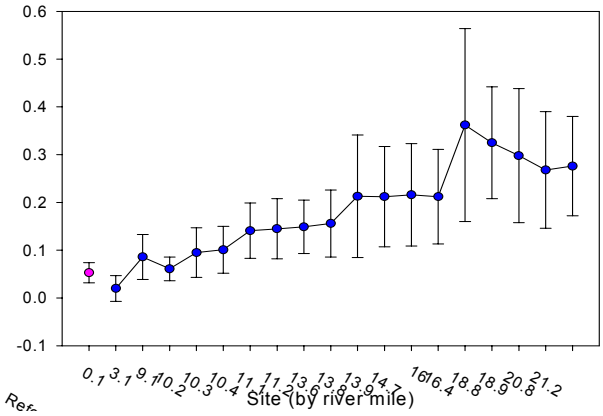


Fig. 3. Total P concentrations averaged from May to September; reported by River Mile.



We measured dissolved inorganic N as NH_4^+ and NO_3^-, however since NH_4^+ concentrations were almost always at the detection limit, we report NO_3^- only, below (Fig 4). Trends in the concentrations were similar to those for total P; there was a general increase in the concentration of NO_3^-N despite concomitant increases in water volume in the river as one heads downstream. NO_3^- concentrations peaked below the waste water treatment facility and then declined somewhat, probably owing to dilution by other stream confluences and biological N consumption. Samples for 2004 were frozen and the DIN data are currently being utilized to prepare stream waters for natural abundance isotope analysis. This analysis will take place spring 2005 and will be

Fig. 4. NO_3 N concentrations averaged from May to September; reported by River Mile.

compared to the isotopic signature of algae collected from the stream over the same period. We will use a simple mixing model to assess the source of N supporting algal growth in the watershed, but this methodology alone does not allow one to assess nutrient limitations on the algal growth and thus "causation" rather, it will give us a sense of where nutrient inputs occur and if they might be associated with point source and non-point source inputs to this river.

Algal Assessments

In 2004, a cool spring with higher than average precipitation delayed onset of algal growth until late August and early September. Algal cover was less than 5% of the substrate in greater than 60% of the sampling sites. Community analyses revealed three dominant filamentous genera: *Spirogyra*, *Mougeotia*, and *Zygnema*. They are all unbranched green algae belonging to the Class Charophyceae and are not indicative of a particular trophic environment.

Implications and Expected Outcomes:

The HBMI and USGS are investing much into the Meduxnekeag River watershed, and this project will add to the effort by defining the nutrient status of the river and studying the dynamics of the algal bloom. It will help the HBMI to determine the necessity for a nutrient monitoring program in the future and to find areas of the watershed to focus nutrient reductions efforts. The Maine DEP is currently developing nutrient and biological criteria (including algae) for the state's rivers. The results from this project will be made available to the DEP to add to their database. The historical algal growth in the Meduxnekeag River is rare for the state, and therefore, nutrient and algal growth data for the river will be valuable in helping to define the range of conditions found in Maine.

Deliverables:

To date, no publications have arisen from this investigation:

Other Activities

Fretwell, L., D.B. Dail, K.E. Webster, and S.H. Brawley. *The relationship between phosphorus and nitrogen concentrations, algal growth, and land use in the Meduxnekeag River watershed*. Poster presented at the 2005 Graduate Student Research Exposition, April 11-12, 2005. Orono, Maine.

Fretwell, L., D.B. Dail, K.E. Webster, and S.H. Brawley. *The relationship between phosphorus and nitrogen concentrations, algal growth, and land use in the Meduxnekeag River watershed*. Poster presented at the 2005 Maine Water Conference, March 22, 2005. Augusta, Maine.

Fretwell, L., D.B. Dail, K.E. Webster, J.S. Kahl, S.H. Brawley, and L. Wilson. *Periphytic algae as an indicator of nutrient loading to the Meduxnekeag River.* Poster presented at the 2004 Maine Water Conference, April 21, 2004. Augusta, Maine.

Fretwell, L., D.B. Dail, K.E. Webster, J.S. Kahl, S.H. Brawley, and L. Wilson. *Periphytic algae as an indicator of nutrient loading to the Meduxnekeag River.* Poster presented at the 2004 Graduate Student Research Exposition, April 12-13, 2004. Orono, Maine.

Valuing Environmental Changes for Decision Making: Dam Removal and Restoration on the Penobscot and Kennebec Rivers

Basic Information

Title:	Valuing Environmental Changes for Decision Making: Dam Removal and Restoration on the Penobscot and Kennebec Rivers
Project Number:	2005ME56B
Start Date:	5/1/2005
End Date:	9/30/2006
Funding Source:	104B
Congressional District:	2
Research Category:	Social Sciences
Focus Category:	Economics, Management and Planning, Methods
Descriptors:	None
Principal Investigators:	Lynne Lewis, Curtis Bohlen, Laura Rose Day

Publication

1. Lewis, L., Bohlen, C., Wilson, S. (submitted 2006) "Dams, Dam Removal and River Restoration: A Hedonic Property Value Analysis." Journal of Contemporary Economic Policy.
2. Robbins, J., Lewis, L. (2006) "Demolish it and they will come: Economic Benefits of Restoring a Recreational Fishery." Executive Summary report to the George J. Mitchell Center for Environmental and Watershed Research. June 2006.

Valuing Environmental Changes for Decision Making: Dam Removal and Restoration on the Penobscot and Kennebec Rivers (Progress Report)

Lynne Lewis, Bates College
Curtis Bohlen, Trout Unlimited
Laura Rose Day, Penobscot Partners

Introduction

On June 25, 2004, a press conference was held at the Veazie Dam to witness the signing of the unprecedented restoration agreement on the Penobscot River. Signing the Penobscot River Restoration Settlement Agreement were Secretary of the Interior Gale Norton, Governor John Baldacci, Chief of the Penobscot Indian Nation Barry Dana, Penobscot Partners Project Director Laura Rose Day and Pennsylvania Power and Light (PPL). The agreement was filed with the Federal Energy and Regulatory Commission (FERC) the following day. Under the agreement, PPL grants a five-year option to purchase three of its dams on the Penobscot River to the Penobscot Restoration Trust. The Penobscot Restoration Trust is made up of a coalition of environmental organizations including the Natural Resources Council of Maine, Trout Unlimited, Audubon Maine, American Rivers, Atlantic Salmon Federation and the Penobscot Indian Nation. The group plans to remove two dams and build a fish bypass at a third, thus freeing up more than 500 miles of the main-stem river for anadromous fish including the endangered Atlantic salmon. The agreement gives PPL Corporation the opportunity to maintain more than 90 percent of its current hydropower generation. The project would be the largest river restoration effort north of the Everglades.

The Edwards Dam on the Kennebec River, which was breached and removed in 1999, was the first major dam to be removed in Maine. Since removal of the dam, anadromous fish, including Atlantic salmon, have returned to the river above the dam site. Aquatic insect populations have grown dramatically. Recreation on the river in the form of fly fishing, canoeing and kayaking has also grown. However, little has been done in the way of post-project research or monitoring. The project has been deemed successful by most observers, but without formal evaluation, few objective measures of "success" are possible.

The need for better post-project monitoring and social-economic evaluation of aquatic restoration projects is widely recognized. The Draft Maine River Restoration User Guide issued in January 2004[1] emphasized the need for a "comprehensive, accurate method for evaluating the beneficial and adverse impacts of a dam removal." This report includes a section highlighting the need for socio-economic valuation. In 2002, the Department of Interior commissioned the Water, Science and Technology Board (WSTB) to undertake an assessment of water resources research funded by federal dollars. At the Universities Council on Water Resources annual conference, in July of this year, Henry Vaux, Chair of the WSTB Committee, presented a keynote talk on the findings. According to Vaux,

[1] Maine State Planning Office, January 27, 2004

one of the priority needs is for *ex-post* analysis of projects and for continued monitoring of current projects; social science research is also lacking. These shortcomings will become increasingly apparent as more and more dams outlive their useful lives and come up for relicensing, both in Maine and across the nation.

The removal of the Edwards dam signaled – or partially triggered – a change in thinking about management of Maine rivers. Discussions over river management are taking place among stakeholders and interested groups from York to Fort Kent. Examples include discussions about dissolved oxygen in Gulf Island Pond on the Androscoggin River and about the scheduled demolition of Fort Halifax Dam on the Sebasticook. Other examples abound. Nearly half a dozen smaller dams have recently been removed or are currently being evaluated for removal. Efforts to establish fish passage at other sites have increased as anadromous fish pass downstream dams that have blocked access for most of a century. The Penobscot River Restoration agreement allows for the removal of two major dams north of Bangor and for fish passage to be built at others. Additionally, the removal of Edwards Dam set a national precedent for removing dams of marginal value. All this activity signals a critical need for estimates of the socio-economic benefits of often expensive restoration efforts.

This has been collecting data to refine valuation methods and assess components of value associated with dam removal. The primary effort has been to obtain and categorize value estimates in a manner that can be generalized for other Maine Rivers and to other kinds of aquatic restoration.

Background

In a report submitted to the Federal Energy and Regulatory Commission (FERC), prior to the decision to remove Edwards Dam, Freeman (1996) reviews and critiques FERC's benefit-cost analysis for the Edwards Dam project. In this report, Freeman emphasizes why non-power values must be included in benefit-cost analysis. FERC did not include any non-power values in its study. (Typically these values are excluded from FERC analyses due to the difficulty of estimation.) As Freeman states, "this is a fatal methodological flaw" (Freeman 1996, p.5). By ignoring and excluding these non-power values in its benefit-cost methodology, FERC made it impossible for the dam removal alternative to ever show a net economic benefit to society. Freeman (1995) estimates the present value of benefits to recreational anglers alone would be at least $36.2 - $48.2 million. This estimate is based on a study by Boyle (1991). This, of course, is a lower bound as it does not include other potential economic benefits. For example, whitewater boating benefits were expected to increase with removal. Additionally, there are other nonmarket benefits and costs, such as habitat enhancements and overall water quality improvements that were not estimated. Evidence to date, suggests that these numbers were, in fact, underestimates.

Interestingly, many outcomes of dam removal are not captured by market values and may be in conflict with one another. Naeser and Smith (1995), for example, examine the conflicts between different instream flow users including anglers and rafters. River-based recreation is not necessarily improved by leaving more water in the river. Many times the

timing of flows is important to recreational users, in which case the effects of dam removal would be different for different users.

The difficulty of nonmarket valuation is well established in the literature and much has been written on methods for nonmarket valuation (Freeman 2003 and Mitchell and Carson 1989, for example). Despite the advancements in methodology, reliable estimates are still difficult to obtain.

Few studies have attempted to estimate the total nonmarket value of a dam removal. Loomis (1996) finds a significant willingness to pay to remove dams in the Pacific Northwest in order to restore salmon and steelhead runs. Loomis uses a contingent valuation survey to obtain estimates of willingness to pay for removing dams on the Elwha River. His results suggest that total nonmarket benefits to all U.S. households of these dam removals fall in the range of $3 – 6 billion. He suggests that this type of "valuation information should be used by FERC in relicensing decisions on the east and west coast" (Loomis, p. 446).

Gonzalez-Caban and Loomis (1997) examine willingness to pay to avoid a dam on the Rio Fajardo in Puerto Rico. They find an annual willingness to pay of $28 per household or $13.09 million when expanded to the one million households in Puerto Rico. They also estimate willingness to pay to preserve instream flows for Rio Mameyes and find an annual household willingness to pay of $27 ($11.33 million).

The above studies used survey methods including contingent valuation and travel cost surveys. Another approach to nonmarket valuation, the hedonic property value method, uses market transactions in order to estimate the marginal prices of the various attributes of housing choice, including environmental quality. While the limitations of hedonic models are well known, they are useful because they allow us to determine whether or not environmental variables are reflected in the housing market.

Models that address environmental externalities characterizing locational choice have a strong spatial component. These spatial components may vary within a watershed, but also may be attributed to the health or quality of the watershed. Only recently have hedonic models addressed the spatial components of environmental quality and how these may relate to home prices (Lewis and Acharya 2004, Paterson and Boyle 2002, Acharya and Bennett 2001, Bockstael, 1996 and Geoghegan et al., 1997).

Proximity to water bodies, such as rivers and lakes, may be an asset to home owners but the relative quality of land and water attributes can result in dis-amenities and reduced home prices. Thus, this method is extremely appropriate for evaluating the impacts of dams and dam removal. To our knowledge, hedonic property value models have not yet been utilized in valuation for dam removal.

Interest in spatial analysis with hedonic property models is increasing as evidenced by the growing number of papers that incorporate spatial issues within hedonic property models. For example, Parsons (1992) uses a repeat sales analysis to study the effect of the

distance that houses are from critical areas where new development is not permitted. Michaels and Smith (1990) and Hite et al. (2001) examine the effects of distance from of hazardous waste sites and landfills respectively. Similarly, Palmquist et al. (1997) investigated how non-farm residences were affected by large hog operations. Most recently, a few studies have addressed the question of scale and patterns in land use (Bockstael, 1996, Geoghegan et al., 1997 and Acharya and Bennett, 2001).
Leggett and Bockstael (2000) present a hedonic analysis of waterfront property with the *a-priori* expectation that owners of waterfront property care about water quality as they have "essentially self-selected for an interest in water activity." To the best of our knowledge, while studies have utilized distance to rivers as an independent variable, distance to a dam has not been examined as potentially affecting property values.

One drawback of this method is that environmental or ecological data that help identify the quality of a neighborhood are often not accessible to housebuyers or may be highly scientific in nature and, therefore, of little consequence to housebuyers. Additionally, many homebuyers may not be aware of this information until after purchasing the home or the information must be inferred by the purchaser. Extremely few studies have incorporated subjective measures of environmental quality, such as those inferred by the buyer. Poor et al. (2001), examine and compare objective measures of water quality with subjective measures based on survey data on individuals' perceptions of quality. Poor et al. examine the convergent validity of objective and subjective measures of water clarity for lakes in Maine using an hedonic property value study. They utilized property sales data, objective scientific measures of water clarity and data from a household survey designed to elicit perceptions of water clarity. Very few other studies have surveyed the purchasers associated with the property value data. (See Poor et al. (2001) for a summary of the literature).

Project Description

This project addresses a gap in the body of knowledge on valuation of river restoration. Requests are frequently made for information on costs and benefits of restoration that can be used in policymaking. Estimates of nonmarket economic values of environmental benefits related to dam removal are especially crucial. Few such estimates exist. Those that do exist for Maine are dated and restricted to recreational benefits. Additionally, no study has gone back to see if predicted nonmarket values (and disvalues) actually developed following dam removal via *ex-post* analysis. The inclusion of hedonic property value studies add subjective measures of environmental quality captured through surveys of preferences and perceived quality.

The ex-post evaluation of the Edwards Dam removal should be informative to future dam removal evaluations. The linking of survey responses to GIS and hedonic models is an important methodological contribution. The combined results should also inform policy-makers.

The overall goals of this project are as follows:

- Refine a combined approach for estimating environmental values relying on both hedonic and survey methods; Estimate values associated with dam removal using

both predictive (Penobscot River) and *ex-post* (Edwards Dam) methods.
- Create an inventory and GIS-based map of properties, property owners, property values and transactions and land use along the lower Penobscot River;
- Design and implement a pilot survey for anglers, recreationists and property owners along the rivers;

The following information has been collected from diverse sources (and analysis of the data has not yet been completed for publication):

- An ex-post (Edwards removal) survey of anglers modeled on Boyle's (1991) study in order to test the validity of his results and determine recreational values since the dam was removed.
- An *a-priori* (Penobscot dam removal) survey of anglers also modeled on Boyle's study.
- A pilot survey of rafters and kayakers on the Kennebec and Penobscot Rivers aimed at capturing additional recreational value, but also aimed at examining perceptions of values.
- A pilot study linking a hedonic property value study to survey of expressed preferences of local residents using computer-generated simulations of what the Penobscot River will look like after dam removal. The study will explicitly incorporate both distance to the river and distance to the dam variables.

The two angler surveys are based to a significant extent on the methods used previously by Boyle, are being carried out by closely supervised undergraduate researchers, as the cornerstone of senior thesis projects. The two pilot studies are intended to explore theory of nonmarket valuation and to demonstrate the feasibility of novel research methods. Theses are being carried out at a relatively small scale while we work to acquire additional funding for a larger project.

Methods

This project combines survey methods with hedonic property value in an attempt to use pieces of each methodology to capture estimates of economic value attributed to changes in environmental quality such as water quality, recreational or habitat improvements. An innovative component of the project is the use of computer generated images of pre-project river views and projected post-project river views in a revealed preference context to help refine estimates of the value of aesthetic changes in the river. These images have been generated by Penobscot Partners and we have permission from them to use them for this project. The project is applying GIS mapping techniques in association with hedonic and survey methods to better understand the spatial (and thus social) distribution of benefits and costs from river restoration efforts.

Results

This report is a progress report because the collection and analysis of the survey data, property valuations. It would be pre-mature to summarize partially analyzed data. A detailed studied, including student's results, will be included at a future date.

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

Basic Information

Title:	A sequential time-weighted average approach for monitoring pesticide levels in Maine surface waters
Project Number:	2006ME83B
Start Date:	9/1/2006
End Date:	8/31/2008
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Toxic Substances, Surface Water
Descriptors:	None
Principal Investigators:	Howard Patterson, Lucner Charlestra

Publication

A SEQUENTIAL, TIME-WEIGHTED AVERAGE MONITORING APPROACH TO DETECT PESTICIDE LEVELS IN MAINE SURFACE WATERS

1. Background

This project aims at addressing the concerns of Maine environmental stakeholders about pesticide concentrations that may negatively impact Atlantic Salmon (*Salmo solar*) habitats in surface waters. In Washington and Hancock Counties watersheds, the pesticides of interest are: phosmet, chlorothalonil, propiconazole and hexazinone. A pilot experiment in summer 2004 showed that the Polar Organic Chemi-cal Integrative Sampler (POCIS) can be effective in measuring pesticide levels in water, thus, offering an alternative to the methods (grab sampling and ISCO autosampler) currently used by the Maine Department of Agriculture. However, there is a need to further the POCIS study both qualitatively and quantitatively by collecting a larger amount of data in the field and by generating, in the laboratory, calibration parameters specific to the pesticides previously mentioned.

2. Objectives

The proposed work for the period of September 2006 to April 2007 was as follows:

1. Trip to Columbia , Missouri, to work with USGS experts on POCIS experiment designs;
2. Perform laboratory studies in order to determine sampling rate data in low and high flow conditions for hexazinone, phosmet, chlorothalonil and propiconazole. Generating specific sampling rates of these chemicals will allow more accurate water concentration calculations, not only within the context of this study, but in future field experiments as well.
3. Progress report including sampling rate data generated for the pesticides.

3. Work carried out

1. September to December 2006

The first semester was devoted to academic formalities like the formation of an advisory committee and presentation of a thesis proposal to the committee. The administrative procedures for the release of the federal match of the project funding were also undertaken during that semester. In the meantime, the literature gathering was initiated. Many articles about pesticide sampling, analysis and modeling in the field and laboratory were collected from different environmental journals.

2. January to April 2007

During the month of February 2007, I traveled to the USGS research center in Columbia (Missouri) in order to meet with Dr. David Alvarez (the designer of the POCIS device) and other staffs. I toured their laboratories and had some fruitful discussions about experimental designs with the POCIS. One important feature of the project is the identification and quantification of the pesticides used on the blueberries from water and the POCIS matrices. This analytical aspect

usually takes up a large part of the budget when carried out by commercial laboratories. Therefore, during the spring semester, I took a class in advanced analytical chemistry that will allow me to carry out the analysis of the pesticides at the University of Maine once the procedures for the extraction and pre-concentration of the samples are optimized.

4. Future work (May to August 2007)

The different constraints related to academic, technical and financial planning delayed the start of the calibration experiments scheduled for the period of January to April 2007. The process will be initiated in May 2007 with the following activities:

1. Analytical methods optimization

Gas chromatography mass spectrometry (GC/MS) will be used for the qualitative and quantitative analyses of the pesticides. Therefore, analytical methods for analyte extraction in surface water and the POCIS sorbent need to be optimized prior to laboratory experiments. Pesticide extraction in POCIS and water matrices will be done according to SOPs provided respectively by the EST laboratory (Saint Joseph, MO) and the Hitchner Hall laboratory at the University of Maine. The analytical method optimization will be undertaken up to the third week of May. Once the whole procedure (extraction, QA/QC, analyte quantitation) is mastered, the POCIS calibration experiment will be set up in the laboratory.

2. Laboratory-controlled experiments

The parameter that will be measured in the laboratory is the sampling rate (R_s). It is an expression of the volume of water cleared of the target analyte per day and is used for estimating pesticide concentration in water from the concentration measured in POCIS deployed in the field. The sampling rate is calculated from laboratory-deployed POCIS by the formula:

$R_s\,(Ld^{-1}) = C_{POCIS} / C_w * t$

Where, C_{POCIS} is the analyte concentration in the POCIS device, C_w is the analyte concentration in the test water, t is the deployment time in day. This model assumes integrative sampling of the test chemicals by the device and requires that their concentrations remain fairly constant throughout the experiment. However, a drop in pesticide concentration can result from physical and chemical processes in the experimental setup (sorption on the walls of test container, metal component of the POCIS, volatilization etc). Therefore, I will conduct some preliminary studies to determine some parameters for the actual experiment.

1) Preliminary studies

The experiments will be conducted in stirred and quiescent conditions. The experimental unit is a ten-gallon glass aquarium (20” x 10” x 12”). Six gallons of water will be put in the tank as a reaction medium. The ideal experimental setup to model river flow would be a flow-through system that ensures water recycling and mixing while maintaining constant concentration of the tested compounds in water (C_w). It takes time to set up such a system, and keeping analyte concentration constant can be difficult. Thus, a simpler and quicker static stirred system will be set up for this first experiment , consisting of one submersible pump placed at the bottom of the tank to stir the system and recycle water inside the tank at a flow rate of $153gh^{-1}$ (flow-through systems may be considered for further experiments)

a. Half-lives determination

Some documents report relatively short half-lives for some of the targeted pesticides (for example 9 hours for phosmet). There is no clear indication as to the conditions under which the experiments have been conducted. I will determine the hydrolysis half-lives ($t_{1/2}$) of the compounds (*without the POCIS device*) according to a 14/10 L/D cycle, using a store-bought timer and light source. The pesticides will be spiked in four tanks at a concentration of $5\mu gL^{-1}$, while four other tanks containing unfortified water will serve as controls. Water samples (500 mL) will be taken every day for one week and analyzed for pesticides.

b. Determination of water renewal schedule

Keeping constant water concentrations with these hydrophilic pesticides can be quite challenging. In order to do so, the test water needs to be replaced periodically. Thus, another exploratory test (*with the POCIS device*) will be conducted at 25 ^{o}C (using heaters) over a seven day-period to roughly determine the timing in concentration decrease and set up a renewal schedule of test water for the actual calibration experiment. Four tanks will be used to conduct this preliminary trial as follows:

(1) The water in two tanks will be spiked with the appropriate amount of stock solutions to maintain a nominal concentration of $5\mu gL^{-1}$. $NaHCO_3$ will be used as pH buffer and $CaCl_2$ will be used to adjust ionic strength. The devices will be put in the tanks a few hours after spiking the water with pesticides.

(2) Six POCIS devices will be placed in each tank. Water in the two other tanks will not contain pesticide and will be used as background controls.

(3) Pesticide concentrations in the tanks will be monitored daily (from day 0 to day 7) by collecting and analyzing 500 mL of water.

(4) Two POCIS will be retrieved and replaced 24 hours, 3 days and 7 days after the deployment for pesticide analysis.

2) Calibration experiments

The actual calibration experiment will be done according to the same procedure described for the renewal schedule. The only change will be that eight tanks will be used in this experiment; that is, four tanks with fortified water and four tanks as blanks.

5. Field experiment

Field deployments of the POCIS are still scheduled to take place in July. However, the actual timing, method and extent of these experiments will depend on the following factors:

- The timing of the laboratory experiments;
- The recommendations of project partners (DEP, ASC, DA) and committee members;
- The cooperation of blue berry growers;
- The collaboration of local organizations in the study locations.

6. Conclusion

The first three trimesters of the project were devoted to academic, technical and financial activities in preparation of the calibration experiments. Beginning in May, The analytical method for pesticide pre-concentration in water sample POCIS sorbent will be optimized, and the experiments will start the first week of June. If the laboratory experiments go as scheduled, field deployments of POCIS will be carried out during the summer.

Identification of Disinfection Byproducts by High Resolution Gas Chromatography Fourier Transform Ion Cyclotron Resonance Mass Spectrometry

Basic Information

Title:	Identification of Disinfection Byproducts by High Resolution Gas Chromatography Fourier Transform Ion Cyclotron Resonance Mass Spectrometry
Project Number:	2006ME84B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Methods, Toxic Substances, Water Supply
Descriptors:	None
Principal Investigators:	Touradj Solouki, John M. Peckenham

Publication

1. Caleb Heffner, Indira Silwal, John M. Peckenham, Touradj Solouki Emerging Technologies for Identification of Disinfection By-Products: GC/FT-ICR MS Characterization of Solvent Artifa cts, in press, Environmental Science & Technology, 2007.
2. Solouki, T.; Szulejko, J. E.; Silwal, I.; Heffner, C., Experimental and Theoretical Approaches: Identification of Disinfection Byproducts in Drinking Water with multidimensional GC/FT-ICR MS, Proceedings of the 54th ASMS Conference on Mass Spectrometry and Allied Topics, 2006, Seattle, Washington.
3. Touradj Solouki, Indira Silwal, John M. Peckenham, Jayendran C. Rasaiah, and Caleb Heffner, Emerging Technologies for Sample-printing and Identification of Disinfection By-Products in Drinking Water: Multidimensional GC/FT-ICR MS and Theoretical Calculations Gordon Conference, August 2006.
4. Touradj Solouki, Abdullah Alfdeilat, Caleb Heffner, Indira Silwal, Remote Sampling and Emerging Mass Spectral Technologies for Analysis of Complex Environmental Samples: Collective Performance Characteristics, Wellington, New Zealand, EnviroAnalysis Conference 7-10 February 2007.
5. Caleb Heffner, Applications of Emerging Analytical Technologies in Environmental Analysis: A Multidimensional Approach, Department of Chemistry, University of Maine, May 2nd, 2007.
6. Touradj Solouki, Caleb Heffner, Indira Silwal, John M.Peckenham, Emerging Technologies for Comprehensive Analyses of Complex Environmental Samples: Theoretical Modeling Combined with ESI and GC/FT-ICR Mass Spectrometry MICROPIOL & ECOHAZARD: 5th IWA Specialised Conference on Assessment and Control of Micropollutants / Hazardous Substances in Water, Frankfurt, Germany, June 2007.

I- Reporting (& Performance) Period: 03/01/2006 – 04/01/2007

This annual report contains the research activities for the USGS funding period (*i.e.*, 03/01/2006 – 04/01/2007).

II- Personnel Directly Involved with the Research:

1. **Touradj Solouki (PI)**: Funding was not requested for the PI but he contributed time to support the overall project. The PI was involved in all aspects of the research, teaching and training activities. During the USGS funding period, the PI, developed mass spectral methods, collected data, presented data in various conferences and meetings, prepared and submitted proposals and manuscripts. In addition, Dr. Solouki supervised an undergraduate student and a graduate student who were directly involved with the USGS supported activities.

2. **John Peckenham (Co-PI):** Funding was not requested for the Co-PI but he was involved in sample preparation, data interpretations, and various significant aspects of the research activities (*e.g.*, proposal and manuscript preparation).

3. **Indira Silwal (Ph.D. Candidate):** Indira is a graduate student in the PI's group and she was supported during the funding period. She was initially a Master's of Science (MS) student in Chemistry. However, her accomplishments with the research activities and successful completion of the comprehensive examinations during the funding period have allowed her to become a Ph.D. candidate. Indira has completed a significant portion of her thesis work, written and successfully defended an NSF style proposal titled "MALDI-TOF MS Study of Identification of the Molecular Content of RBL (Rat Basophilic Leukemia) at a Single Cell level". The anticipated completion date for Indira's thesis work is December 2007. Indira has co-authored a manuscript that has been accepted and is in press (Environmental Science and Technology); moreover, she is in process of finishing another manuscript titled "Determination of Gas Phase Basicities, and Proton

Affinities Using Gas Chromatography/Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (GC/FT-ICR MS) and Ab- initio Calculations".

4. **Caleb Heffner (Undergraduate Research and Thesis)**: Caleb is an undergraduate student in the Chemistry Department (Bachelor of Science, BS) who has been quite prolific with his research activities. Based on his research work, Caleb submitted a proposal titled "Identification of Disinfection By-Products in Drinking Water Using Multi-Dimensional GC/FT-ICR MS and Theoretical Calculations" to Pfizer. In addition, he was the first author on a paper that was submitted to the Environmental Science and Technology. This manuscript was reviewed and accepted for publication. Moreover, based on his research conducted under the USGS funding, Caleb has been selected as the ***Recipient of 2007 J. Morris Student Innovation Award*** *(only two of these awards are given annually university wide)*. Caleb's undergraduate thesis is titled "*Applications of Emerging Analytical Technologies in Environmental Analysis*" and he will be defending it in May 2007.

III- Budget: Budget was adequate to fulfill the initially proposed USGS tasks. Additional budgetary details are available upon request. The major portion of the funding was for the student support and cryogens for normal operation of the superconducting 7 tesla magnet (*i.e.*, FT-ICR mass spectrometer and sample preparation).

V- Other Invited Oral Presentations Acknowledging The USGS Support:

1. Touradj Solouki, "National Science Foundation & Azerbaijan National Academy of Sciences– "Collaborative Research Opportunities - Civilian Research Development & Foundation (CRDF)", formal meetings with the President of ANSF ANAS, *Baku Azerbaijan*, January **2007**.

2. Touradj Solouki, "Fourier Transform Ion Cyclotron Resonance MS– Surpassing World Record Mass Resolving Power in Gas Chromatographic Analyses of Complex Mixtures", *University of Sharif*, May, **2006**.

3. Touradj Solouki, "Analytical Challenges in X-omics and Emerging Fourier Transform Ion Cyclotron Resonance Mass Spectrometry Capabilities for Complex Sample Characterization", Bilkent University, Ankara Turkey, March 16, **2007**.

4. Touradj Solouki, "Ongoing Improvements to Ionization Techniques and Fourier Transform Ion Cyclotron Resonance Mass Spectrometry Capabilities: Unraveling Nature's Complexities", *Ankara, Turkey METU University*, March 17, **2007**.

7. Touradj Solouki, "Emerging & High Performance Instrumentation for Sampleprinting in Forensic and Bioanalytical Sciences", *University North Texas*, April, **2006**.

VI - Theses Prepared / Under Preparation:

1. Undergraduate Student Thesis:
    a. Caleb Heffner, ""*Applications of Emerging Analytical Technologies in Environmental Analysis"*, three chapters written and reviewed. Will be defended in May **2007**.

2. Graduate Student Thesis (Ph.D.):
    a. Indira Silwal, *"Experimental and Theoretical Approaches to Determine Thermodynamical Parameters for Multidimensional Mass Spectrometry"*, in preparation.

VII - Proposals Prepared Based On The Data Acquired From This Project:

PI:	Touradj Solouki
Title:	Multidimensional GC/FT-ICR MS: Characterization of Environmental Contaminants and Cancer Biomarkers at a High Level of Confidence"
Source of Support:	NSF
Total Award Amount:	$ 384694
Total Award Period:	06/01/06- 05/31/09
Status:	Pending

PI:	John Peckenham
Co-PI:	Gail Lipfert, Touradj Solouki, Andy Tolman
Title:	"The influence of chloride and natural organic matter gradients on disinfection by-product formation in Maine"
Source of Support:	USGS
Total Award Amount:	~ $ 45000
Total Award Period:	04/01/07- 03/31/09
Status:	Funded

PI:	Touradj Solouki
Title:	"Early Detection of Epithelial Ovarian Cancer Using Exhaled Breath Markers: GC/FT-ICR Mass Spectrometry and Canine Olfaction"
Source of Support:	DOD
Total Award Amount:	$ 473549
Total Award Period:	02/01/07- 01/31/09
Status:	Funded

Does food-web structure mediate landscape-scale responses of Maine lakes to nutrient enrichment?

Basic Information

Title:	Does food-web structure mediate landscape-scale responses of Maine lakes to nutrient enrichment?
Project Number:	2006ME86B
Start Date:	1/7/2006
End Date:	6/30/2008
Funding Source:	104B
Congressional District:	Second
Research Category:	Water Quality
Focus Category:	Ecology, Surface Water, Non Point Pollution
Descriptors:	None
Principal Investigators:	Katherine Webster, Linda Bacon, Laura R Wilson

Publication

RESEARCH:

Objectives:

The traditional focus of lake rehabilitation efforts has been on controlling the sources of nutrients that eventually lead to chronic algal blooms, anoxic hypolimnia and degraded water clarity. This 'bottom-up' approach is obviously necessary for improving or maintaining lake water quality. However, an increasing body of evidence suggests that 'top-down' controls play a major role in how nutrient loading is expressed in enriched lakes (Carpenter et al. 1995; Gliwicz 2002; Stemberger and Miller 2003). From this perspective, the relative dominance of the fish assemblage by planktivores (zooplankton-eating fish) over piscivores (fish-eating fish), influences algal biomass and water clarity. Lakes with intense planktivory tend to have smaller cladocerans, which are less efficient grazers of algae. Under this scenario, algal populations are released from control by grazing leading to reduced water clarity (Carpenter et al. 1995). The size structure of the cladoceran community, and especially *Daphnia* species, has been posited as one of the key indicators of the resilience of lakes to eutrophication (Carpenter et al. 1995). Over the past century, fish introductions through official and illegal means as well as dispersal through hydrologic corridors, have dramatically altered the structure of aquatic communities in the Northeast US (Whittier and Kincaid 1999). By altering food web structure and the associated energy transfers between trophic levels, introduced fish may further reduce the resilience of lakes to nutrient enrichment and make traditional lake rehabilitation approaches less effective. The landscape-scale implications of these fish community changes and, in particular, their interaction with other anthropogenic stressors have important implications for biodiversity, sustainability, and management of aquatic ecosystems.

Our research has the overarching goal of determining if top-down effects of resident fishes mediate the response of lake food webs, particularly cladoceran size structure, to eutrophication at the landscape scale. We ask whether heterogeneity in cladoceran size structure across a gradient of lake nutrient status is related to the intensity of planktivory and, whether that relationship differs among lakes in predictable ways.

Our specific objectives are:

1) To create a hierarchical model that defines the landscape features and lake characteristics (both physical and chemical) that influence lake trophic state variables in order to isolate the influence of cladoceran size structure.
2) Assess the role of top-down processes on lake responses to nutrient enrichment by examining the influence of cladoceran size structure (measured as body size indicators and species ratios) on water clarity – nutrient relationships in Maine lakes and how that is influenced by the assemblage of fish species in the lake.
3) Develop, test and evaluate outreach materials (websites, presentations) that inform lake users of these processes and relationships.

Methods:

We are using an extensive dataset and archived zooplankton samples collected by the Maine Department of Environmental Protection (MDEP) as part of the Baseline Monitoring Program. The MDEP collected zooplankton samples, nutrient and trophic status data, and water chemistry from a widely dispersed set of ~500 lakes between 1996 and present. We have assembled associated hydrogeomorphic data on lake and catchment morphometry, hydrologic position, geology and elevation as well as data on human disturbance such as land cover near the lake, road density, and population density and ecoregion. These features define the hydrogeomorphic framework for classifying lakes. Within each lake class, we will select lakes that represent trophic gradients in total phosphorus and humic color. Mean body length for each cladoceran will be determined for a total of ~200 individuals using a dissecting scope equipped with a digital camera. Lengths are then determined from these images using ImageJ software (http://rsb.info.nih.gov/ij/) and collated by genus. We will do the body size analyses in summer 2007. From these data, we will calculate body size metrics such as the indices developed by Stemberger and Miller (2003) and the ratio between the abundances of *Daphnia* and *Bosmina* (Kitchell and Kitchell 1980). These indices will be related to trophic status measures, such as TP, Secchi transparency and chlorophyll a, within hydrogeomorphic classes. Statewide data on fish assemblages are limited to presence/absence data collected by the Maine Department of Inland Fisheries and Wildlife over the past 50-100 years. From these assemblage data we will develop an index of fish planktivory. For example, lakes with planktivores such as white perch or alewife have potential to develop abundant populations that have strong effects on cladoceran community size structure.

Importance:

Results of our proposed research will have two immediate benefits, an improved understanding of how food web structure interacts with nutrient enrichment on the landscape scale, and application of these results in the development of new and novel tools and indices for lake assessment and management. Our partnership between academic and state management institutions will further be utilized to develop and test outreach materials to educate the public on the importance of preventing fish introductions that alter lake foodweb structure.

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STUDENT SUPPORT:

This research supports Elizabeth Whitmore, an M.Sc. candidate in Ecology and Environmental Sciences at the University of Maine. She began her program last August and is on target to finish her thesis by June 2008.

Information Transfer Program

The Senator George J. Mitchell Center for Environmental and Watershed Research

John Peckenham, WRRI Director & Assistant Director Mitchell Center
Dr. David Hart, Director Mitchell Center

Jennifer Boothroyd, Scientific Technician(3/06-7/06)
Ruth Hallsworth, Outreach and Development Manager
Tanya Hyssong, Laboratory Manager(3/06-5/06)
Ken Johnson, Field Coordinator (3/06-12/06)
Sarah Nelson, Assistant Scientist
Kim Raymond, Administrative Assistant
Catherine Schmitt, Research Assistant/Science Writer
Dr. Peter Vaux, PEARL Project Director

Introduction

Linking the academic community with state and federal agencies, environmental organizations, and private companies is a central part of the mission of the Mitchell Center and the Water Resources Research Institute. The Mitchell Center serves the State of Maine as a point of access to the substantial technical abilities of the University of Maine on issues of water resources

A new program of the Mitchell Center, the Environmental Solutions Initiative (ESI), will substantially assist us with our information transfer efforts for the WRRI program. Begun in July 2006, the purpose of the Environmental Solutions Initiative (ESI) is to connect the diverse expertise and problem-solving capacity in the University of Maine System to Maine's need for more effective environmental policies and practices. The objective is to work simultaneously towards the common goals of creating a strong economy, robust communities, and a clean environment. In January, 2007, ESI launched a pilot project to explore the social, economic, and environmental effects of alternative development scenarios in the lower Penobscot River watershed and bay. Water resources research and information transfer related to land use change in Maine will significantly benefit from the launch of this pilot project.

The Mitchell Center continues to work to disseminate research results, organize meetings, participate in statewide forums, serve on committees dealing with water resource issues, work with teachers and students, and conduct special projects.

Enhancing Lakefront Buffer Adoption through Social Marketing (pilot project)

Basic Information

Title:	Enhancing Lakefront Buffer Adoption through Social Marketing (pilot project)
Project Number:	2005ME81B
Start Date:	5/1/2006
End Date:	9/30/2007
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Education, Non Point Pollution, Methods
Descriptors:	None
Principal Investigators:	Laura R Wilson, John Jemison

Publication

Enhancing Lakefront Buffer Adoption Through Social Marketing

Background

The leading causes of water pollution in the state of Maine include nutrient overloading (phosphorus and nitrogen), as well as silt and suspended solids. This project is designed to address these causes by encouraging the use of vegetative buffers on lakefront property. The goals are to identify barriers to developing lakefront buffers and to develop marketing tools to effect behavior concerning installation and maintenance of lakefront buffers.

Project Staff

In addition to Principal Investigators Wilson and Jemison, two undergraduate Research Assistants (Theodore Smyth and Kate Gaudet) worked on this project in year one.

Target Audience Information

In order to investigate landowner perceptions of water quality and the possible perceived benefits to buffer installation, two focus groups were conducted by undergraduate research assistant Theodore Smyth on July 17th and July 19th with Pushaw Lake residents. Protection of Human Subjects Review approval was obtained prior to the focus groups and the survey. Focus group participants indicated their interest in gardening and landscaping, and their lack of knowledge about what plants would be suitable for landscapes surrounding the lake. Using information from the focus groups, a survey was generated to be mailed to Pushaw Lake residents. The survey focused on

investigating residents' knowledge of water quality and the benefits of vegetated buffers as well as to assess the willingness of residents to participate in a water quality program. Participants were asked to respond to each statement by choosing one of the following: Strongly agree, Agree, Neither agree nor disagree, Disagree, or Totally disagree. Of approximately 300 surveys mailed, 74 responses were received, for a 25 percent response rate. The survey questions and associated responses were as follows:

General questions about Pushaw and water quality:

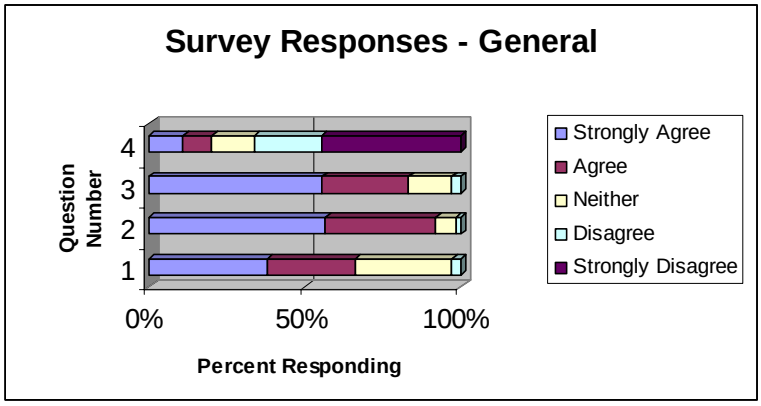

Figure 1: Responses to general survey questions:

1. The phosphorus and nitrogen levels in Pushaw Lake are too high.
2. I am concerned about the water quality of Pushaw Lake.
3. I am willing to take action/make changes on my lake property to protect the water quality of Pushaw.
4. What I do on my lakefront property has little or no effect on Pushaw Lake water quality.

From these answers, we determined that the lakefront landowners who responded to the survey do have concerns about the water quality of Pushaw, have some knowledge of nutrient and water quality issues, and realize that their lakefront property may be contributing to the rising levels of phosphorus in Pushaw. A large percentage of respondents indicated a willingness to make changes on their property in order to protect the lake.

Landscaping questions:

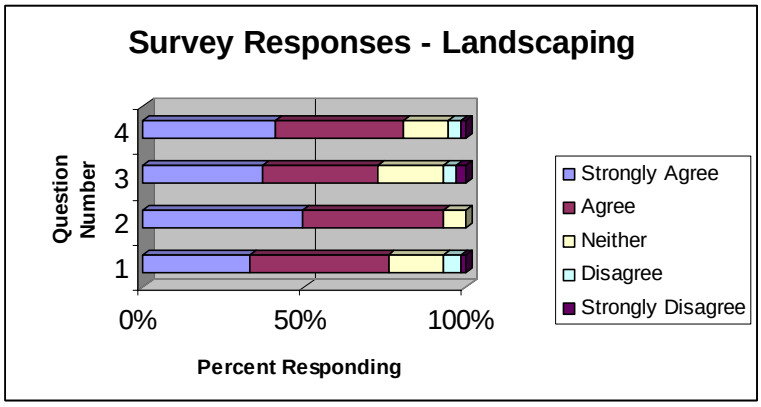

Figure 2: Responses to survey questions about landscaping:

1. I enjoy landscaping and working around my lakefront property.
2. I am interested in lake-friendly landscaping.
3. I would like to purchase a package of pre-selected plants for landscaping if it was available locally/specific to my area.
4. I would likely do lake-friendly landscaping if there were a list of helpful plants for my area.

As indicated initially by our focus group participants, the survey respondents are interested in landscaping, and they indicated an interest in either purchasing pre-selected groups of plants, or in being provided a list of plants suitable for their growing conditions.

The focus group participants also suggested that rewards programs such as the Maine Department of Environmental Protection's "LakeSmart" program may act as an incentive to landowners, or that landowners would participate in informational meetings or workshops. They suggested that incentives such as food or entertainment could be used to increase participation in informational workshops. These suggestions were also tested with the survey:

Additional Survey Questions:

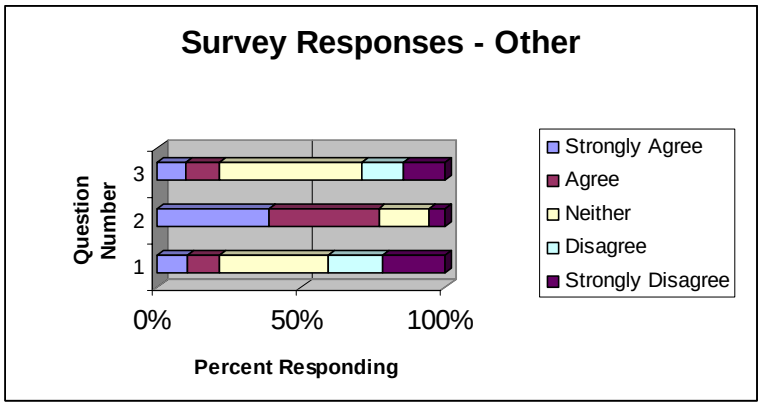

Figure 3: Responses to additional survey questions:
1. Being recognized with a plaque of having my name appear on a local list for having a lake-friendly landscape is important to me, and would motivate me to change my current practices and improve my property.
2. I would likely attend an informational meeting on how I could help protect Pushaw Lake.
3. I would be more likely to attend such a meeting if food would and entertainment would be provided.

From these responses, we determined that using the Maine Department of Environmental Protection's "LakeSmart" program was not a suitable marketing approach with these residents. It is interesting that so high a percentage of respondents indicated willingness to attend an information meeting; historically such meetings generate poor turnouts.

Marketing Approach #1: Lakeside Landscapes

The results of the survey then contributed to the design of a vegetated buffer program entitled "Lakeside Landscapes." Lakeside Landscapes is a program designed to encourage landscaping of lakefront property in order to improve water quality. Incentives include the choice of two, discounted, pre-designed landscapes; Shady Scenery and

Sunburst. Layout designs resulted from consultation with a professional landscaper so as to ensure the best plants for the Pushaw Lake area. The Shady Scenery package includes shade tolerant plants. In contrast, the Sunburst package includes plants that require at least 6 hours of sunlight daily. Residents can choose the package that best suits their needs.

Two target mailings including brochure detailing the project and ordering information were sent to residents of Pushaw Lake. The first mailing targeted the Cedar Breeze area of Glenburn and the second mailing targeted residents of Perk O Rock Landing, Gould Road, Lucky Landing, and Hemlock Point Road in Glenburn and Orono.

Mailing number one consisted simply of the brochure, and a suggested layout scheme for each landscape package. Mailing number two included the brochure and layout schemes, and also a letter detailing water quality benefits. Along with the letter, a flyer advertising master gardener assistance for planting was included as well.

Approach number one focuses on consumer wants (packaged landscapes) and uses discount packages as incentives. Approach number two attempts to address consumer wants as well as desire to participate in water quality improvement projects.

Marketing Approach #2: Perennial Party

Given the results of the survey, a logical marketing technique to use would be an informational meeting to discuss water quality issues on Pushaw. However, with the low turnout in similar meetings held by PI Wilson, the decision was made to use the successful examples of “Pampered Chef®” or “Tupperware®” parties and hold a Perennial Party in the spring of 2007 for targeted residents on a neighborhood scale.

Evaluation

Evaluation will take place in the late summer/fall of 2007.

Maine WRRI IT FY06

Basic Information

Title:	Maine WRRI IT FY06
Project Number:	2006ME93B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	2
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publication

1.

Publications

Peer-reviewed articles.

NOTE: Sarah Nelson was Guest editor of an Environmental Monitoring and Assessment special issue, 2007: Mercury and nitrogen biogeochemistry in paired watershed studies at Acadia National Park, Maine, USA. Volume 126, Numbers 1-3. Papers listed below. [Sarah Nelson, Ken Johnson and John Peckenham are co-authors on many of these papers] ***

Tonnessen, K. and D. Manski, 2007. The Contribution of Acadia PRIMENet Research to Science and Resource Management in the National Park Service. Environmental Monitoring and Assessment 126(1-3): 3-8. DOI: 10.1007/s10661-006-9327-1

Kahl, J.S., **S.J. Nelson**, I. Fernandez, T. Haines, S. Norton, G.B. Wiersma, G. Jacobson, A. Amirbahman, **K. Johnson**, M. Schauffler, L. Rustad, K. Tonnessen, R. Lent, M. Bank, J. Elvir, J. Eckhoff, H. Caron, P. Ruck, J. Parker, J. Campbell, D. Manski, R. Breen, **K. Sheehan** and **A. Grygo**, 2007. Watershed Nitrogen and Mercury Geochemical Fluxes Integrate Landscape Factors in Long-term Research Watersheds at Acadia National Park, Maine, USA. Environmental Monitoring and Assessment 126(1-3): 9-25. DOI: 10.1007/s10661-006-9328-0

Wiersma, G.B.., J.A. Elvir and J.D. Eckhoff, 2007. Forest Vegetation Monitoring and Foliar Chemistry of Red Spruce and Red Maple at Acadia National Park in Maine. Environmental Monitoring and Assessment 126(1-3): 27-37. DOI: 10.1007/s10661-006-9329-z

Schauffler, M., **S.J. Nelson**, J.S. Kahl, G.L. Jacobson, T.A. Haines, W.A. Patterson and **K.B. Johnson**, 2007. Paleoecological Assessment of Watershed History in PRIMENet Watersheds at Acadia National Park, USA. Environmental Monitoring and Assessment 126(1-3): 39-53. DOI: 10.1007/s10661-006-9330-6

Johnson, K.B., T.A. Haines, J.S. Kahl, S.A. Norton, A. Amirbahman and **K.D. Sheehan,** 2007. Controls on Mercury and Methylmercury Deposition for Two Watersheds in Acadia National Park, Maine. Environmental Monitoring and Assessment 126(1-3): 55-67. DOI: 10.1007/s10661-006-9331-5

Nelson, S.J., K.B. Johnson, J.S. Kahl, T.A. Haines and I.J. Fernandez, 2007. Mass Balances of Mercury and Nitrogen in Burned and Unburned Forested Watersheds at Acadia National Park, Maine, USA. Environmental Monitoring and Assessment 126(1-3): 69-80. DOI: 10.1007/s10661-006-9332-4

Nielsen, M.G. and J.S. Kahl, 2007. Nutrient Export from Watersheds on Mt. Desert Island, Maine, as a Function of Land Use and Fire History. Environmental Monitoring and Assessment 126(1-3): 81-96. DOI: 10.1007/s10661-006-9333-3

Peckenham, J.M., J.S. Kahl, **S.J. Nelson, K.B. Johnson** and T.A. Haines, 2007. Landscape Controls on Mercury in Streamwater at Acadia National Park, USA. Environmental Monitoring and Assessment 126(1-3): 97-104. DOI: 10.1007/s10661-006-9334-2

Bank, M.S., J.R. Burgess, D.C. Evers and C.S. Loftin, 2007. Mercury Contamination of Biota from Acadia National Park, Maine: A Review. Environmental Monitoring and Assessment 126(1-3): 105-115. DOI: 10.1007/s10661-006-9324-4

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Longcore, J.R., T.A. Haines and W.A. Halteman, 2007. Mercury in Tree Swallow Food, Eggs, Bodies, and Feathers at Acadia National Park, Maine, and an EPA Superfund Site, Ayer, Massachusetts. Environmental Monitoring and Assessment 126(1-3): 129-143. DOI: 10.1007/s10661-006-9326-2

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Fingerut, J.T., **D.D. Hart**, and J.N. McNair. 2006. Silk filaments enhance the settlement of stream insect larvae. Oecologia 150(2): 202-212.

Skalak, K.J., J. Pizzuto, and **D.D. Hart**, in review. Predicted long-term recovery of bedrock influenced streams from dam removal in the mid-Atlantic region. Journal of the American Water Resources Association.

Peckenham, J. M., (in press) The persistence of MtBE in groundwater, World Water.

Peckenham, J. M., J. Nadeau , R. Behr and A. Amirbahman (in press) Release of Nitrogen and Trace Metal Species from Field Stacked Biosolids, Waste Management and Res.

Peckenham, J. M., J. Kahl, S. Nelson, K. Johnson, and T. Haines (2007) Landscape controls on mercury in streamwater at Acadia National Park, USA, Env. Monit. Asses., 126, pp. 97-104.

Wagner, T., P. Soranno, K. Spence Cheruvelli, W.H. Renwick, K.E. Webster, **P.D. Vaux** and R.J. Abbitt. (submitted 2007). Quantifying sample biases of inland lake sampling programs in relation to lake surface area and land use/cover. Environmental Monitoring and Assessment.

Webster, K., **P.D. Vaux**, T. Asplund, L. Bacon, and J. Connor. (submitted 2007). An empirical evaluation of the nutrient color paradigm for lakes. Limnology and Oceanography.

Reports and Miscellaneous Publications.

Hallsworth, R. 2006. Waterlines…in brief. Web-based news sheet, September 7, 2006. http://www.umaine.edu/waterresearch/outreach/in_brief_9_06.htm.

Hallsworth, R. 2006. Waterlines…in brief. Web-based news sheet, October 6, 2006. http://www.umaine.edu/waterresearch/outreach/in_brief_10_06.htm

Hallsworth, R. 2006. Waterlines…in brief. Web-based news sheet, October 23, 2006. http://www.umaine.edu/waterresearch/outreach/in_brief_10_06_II.htm.

Hallsworth, R. 2006. Waterlines…in brief. Web-based news sheet, November 13, 2006. http://www.umaine.edu/waterresearch/outreach/in_brief_11_06_1.htm.

Hallsworth, R. 2007. Waterlines…in brief. Web-based news sheet, January 16, 2007. http://www.umaine.edu/waterresearch/outreach/in_brief_1_07.htm.

Hallsworth, R. 2007. Waterlines…in brief. Web-based news sheet, January 30, 2007. http://www.umaine.edu/waterresearch/outreach/in_brief_1_07_II.htm

Nelson, S.J., J. S. Kahl, I. J. Fernandez, K. D. Sheehan, A. Grygo Diamond, K. B. Johnson, K. C. Weathers, February, 2007. Final Report: Understanding atmospheric deposition to complex landscapes at Acadia National Park, Maine, 2002-2005. National Park Service, Northeast Region, Technical Report NPS/NER/NRTR-2007/080.

Nelson, S.J., August 2006. Quicksilver from the skies: mercury in snow at Acadia National Park. Acadia Partners Report 2006-01. Published online: http://www.acadiapartners.org/pubs/Nelson_Report.pdf

Rosfjord, C.H., J.S. Kahl, K. Webster, **S. Nelson**, I. Fernandez, L. Rustad, R. Stemberger, 2006. Final Report: Acidic deposition-relevant changes in lake chemistry in the EPA Eastern Lake Survey, 1984-2004. Submitted to USDA NSRC.

Sills, M., **J. Peckenham**, and N. Serrell (2006) Arsenic Water Treatment Life Cycle (conceptual model poster), http://www-apps.niehs.nih.gov/sbrp/3/arsenic/index.cfm.

Schmitt, C. 2006 We all have a stake in Maine Lakes, brochure produced in partnership with Maine Congress of Lake Associations.

Vaux, P and **Hallsworth, R**. 2006. PEARL News. Web-based news sheet, July 2006. http://pearl.maine.edu/about/news_7_06.htm.

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Vaux, P., Kramar, D. and **Hallsworth, R**. 2006. PEARL site development for Atlantic salmon data: Phase 2. Final report to Atlantic Salmon Commission. 24 pp.

Vaux, P. and **Hallsworth, R**. 2006. PEARL site development and management. Report to ME Dept. of Environmental Protection. 14 pp.

Theses.

Diehl, M. Using stream chemistry to evaluate experimental acidification and natural recovery in the paired catchments at the Bear Brook Watershed in Maine (1989-2003). MS thesis. April 2006.

Fretwell, E., 2006. The Temporal and Spatial Relationship Between Phosphorus and Nitrogen Concentrations, Algal Growth, and Nutrient Sources in the Meduxnekeag River Watershed. M.S. Thesis. University of Maine.

Ness, K., 2006. The Effects of Shoreline Development on Lake Littoral and Riparian Habitats: Are Shoreline Protection Regulations Enough? M.S. Thesis. University of Maine.

Thornton, T., 2006. Hexazinone Use on Maine's Blueberry Growing Regions: Environmental Impacts to Surface and Ground Water. M.S. Thesis. University of Maine.

Professional Presentations

Boothroyd, J., Vaux, P., Shannon, M., **McCabe, S.** Waterlogs: A 2005 Survey of Maine Lake Associations. Maine COLA Annual Conference, University of Maine Farmington, June, 2006.

Lipfert, G. and J. Peckenham (2007) Cycling of arsenic through human water usage and water treatment, Northeast Section Geological Society of America, Durham, NH, March 12-14, 2007.

Hart, D.D. 2007. Strengthening science-engineering partnerships for increased understanding and improved management of instream flows. Plenary lecture. Sixth International Symposium on Ecohydraulics. Christchurch, New Zealand. February 20, 2007.

Hart, D.D. 2007. Developing a Watershed Planning Tool to Prioritize Riparian Restoration Activities. ME DEP Conference on Buffers, 9 November 2006.

Hart, D.D. 2006. SimWatershed: A Prototype Tool to Help Guide Riparian Restoration Planning. New England Interstate Water Pollution Control Commission meeting, Lowell, MA. Dec. 6, 2006.

Nelson, S.J., K.B. Johnson, D.P. Krabbenhoft, C.S. Loftin, K.C. Weathers. 2006. Oral (accepted): Deposition, re-emission, and evasion: snow sampling provides estimates of mass fluxes in winter at Acadia National Park, Maine, USA. Eighth International Conference on Mercury as a Global Pollutant, Madison, WI, August 6-11, 2006.

Nelson, S.J. 2006. Oral: Snow mercury flux at Acadia National Park, Maine. Canon National Parks Science Scholars Program Annual Retreat, Waterton, Alberta, CAN, May 15, 2006.

Nelson, S.J., K.B. Johnson. 2006. Invited Field Lecture: Acadia National Park paired research catchments. For Bates College class, "Valuation of Human-Altered Ecosystems", Northeast Harbor, ME, May 3, 2006.

Nelson, S.J., K.B. Johnson, J.S. Kahl, I.J. Fernandez, 2006. Oral, invited: Watershed mercury geochemical fluxes integrate landscape factors in long-term research watersheds. New England Interstate Water Pollution Control Commission 2006 Northeast Regional Mercury Science & Policy Conference, Newport, RI, April 26-27, 2006.

Nelson, S.J., K.C. Weathers, C.S. Loftin, K.B. Johnson, J.S. Kahl, 2005. Poster and abstract: Pick your season: under-estimation (summer) and over-estimation (winter) of total mercury deposition by MDN collection methods at Acadia National Park, Maine. Maine Water Conference, Augusta, ME, March 22, 2006.

Peckenham, J.and G. Lipfert (2007). Approximating the Fate of Arsenic-Bearing Residuals (ABR) From Maine's Drinking Water, Maine Water Conference, March 21, 2007.

Peckenham, J. (2007). Estimating the Production of Arsenic-Bearing Residuals (ABR) From Maine's Drinking Water, Northeast Section Geological Society of America, Durham, NH, March 12-14, 2007.

Peckenham, J. and T. Thornton (2006) The Impact of Gravel Pit Mining on Water Quality, American Water Resources Association Annual Meeting, Baltimore, Maryland, November 9, 2006.

Peckenham, J. (2006) Spring Water versus Groundwater – What's the Difference? Maine Water Conference, Augusta, Maine, March 22, 2006.

Peckenham, J. (2007) Chloride Gradients and the Formation of Disinfection By-Products, American Water Works Source Water Protection Symposium, Savannah, GA, January 28-31, 2007.

Peckenham, J. (2007) SWWAT: Source Water Warning Technology: Using Algae as a Biosensor, American Water Works Source Water Protection Symposium, Savannah, GA, January 28-31, 2007.

Peckenham, J. (2006). Estimating the Production of Arsenic-Bearing Residuals (ABR) From Maine's Drinking Water, SBRP- Arsenic in Landfills, Boston, MA, October 2-4, 2006.

Schmitt, C. 2006. What Lies Between: The Penobscot River Estuary, poster presented at the Maine Water Conference, March 2006.

Schmitt, C., and P. Vaux. 2006. "Aquatic Biodiversity of the Maine Mountains," Maine Mountain Conference, Rangeley, ME, October 21, 2006.

Schmitt, C. 2006. "Penobscot River Environmental History," presentation to Senior Honors English class on Rivers and American Literature (K. Ellis), October 3, 5, 12, 2006, Veazie and Orono, ME.

Schmitt, C., G. Aponte-Clarke, and J. Reardon. 2006. "Penobscot River Restoration Project and the Science Steering Committee," Gulf of Maine Council on the Marine Environment Stream Barrier Removal Monitoring Workshop, June 20, 2006.

Schmitt, C. 2006. "Restoration Narratives: The Penobscot River Example," Association for the Study of Literature and Environment, Summer Symposium, Farmington, ME, June 3, 2006.

Schmitt, C. 2006. Discussion of Penobscot River issues with students from College of the Atlantic, May 23, 2006, Veazie, ME.

Schmitt, C., and C. Daigle. 2006. Discussion of Penobscot River issues, "Talk of the Towns," WERU Community Radio, March 24, 2006.

Schmitt, C. 2006. "The Mitchell Center, Maine Sea Grant, and the Penobscot River," Penobscot Salmon Club, March 8, 2006.

Vaux, P. and Olivero, A. 2006. "Maine's freshwater biodiversity: spatial and temporal patterns." Presentation at New England Association of Environmental Biologists. Bethel, Maine. March 2006.

Conferences, Workshops, Annual Meetings

Maine Water Conference 2006

The twelfth annual Maine Water Conference took place on Wednesday, March 22, 2006 at the Augusta Civic Center, Augusta, Maine. The conference attracts over 350 attendees from across Maine, and has become the annual meeting place for water resource professionals. Conference co-chairs for the 2006 conference were Nancy Beardsley, Maine Drinking Water Program, and Peter Vaux, Mitchell Center. Plenary speakers included: Colin Apse, The Nature Conservancy; Patrick Donohue, International Bottled Water Association; Andrew Fisk, Maine Department of Environmental Protection; and Kathleen Fallon Lambert, Hubbard Brook Research Foundation. Concurrent session included talks and discussions on bottled and bulk water issues, landscape-level approaches to aquatic ecosystem conservation, conservation of freshwater species and communities, obstacles to fish passage, water science education for the public, and a policy roundtable. The poster session featured juried competitions for graduate, undergraduate and high school students. The Maine Water Conference is sponsored by the following organizations: U.S. Geological Survey, Maine Water Resources Research Institute, Mitchell Center, Maine Drinking Water Program, Portland Water District, Aqua Maine, Maine Dept. of Environmental Protection, Maine Geological Survey, Maine Coastal Program, Maine Rural Water Association, Maine Wastewater Control Association, Maine Water Utilities Association, Maine Congress of Lake Associations, Maine Volunteer Lake Monitoring Program, UMaine Cooperative Extension.

Public Service

Media/Press

Munson, D. Understanding and Protecting Maine's Environment. New Mitchell Center director David Hart links knowledge to action. University of Maine press release, August 2006.

Schmitt, C. UMaine Research on Mercury Pollution Featured at International Meeting. Mitchell Center press release, August 2006.

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

- Penobscot River Keepers (~500 students on the river)
- GET WET! (~75 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
- Private Well Initiative

Sarah Nelson

- MDI Water Quality Coalition student mentor, 2006-2007
- Skowhegan High School Environmental Chemistry Water Project mentor, 2006
- January Intersession for High School Students at Schoodic Education and Research Center - Winter watershed geochemistry field class: Geochemical signatures across the landscape, January 2007.
- Appalachian Trail Environmental Monitoring Program, Water Quality Working Group, 2006-present
- Coordinator, University of Maine Mercury Research Group, 2006-present
- Northeast Temperate Network Water Quality Monitoring Workgroup, 2006
- Acadia Research Opportunities Catalog Physical Sciences Panel, 2006
- Professional Employees Advisory Council
- Skowhegan High School Environmental Chemistry Water Project mentor
- Maine Water Conference Organizing Committee
- Chair, Planning Board, Town of Clifton, Maine

Peter Vaux

- Board member and Treasurer, Maine Volunteer Lake Monitoring Program
- Development of databases and on-line data resources with Mount Desert Island Water Quality Coalition
- Development of databases and on-line data resources Union River Watershed

Catherine Schmitt

- Editor, Penobscot and Eddington Salmon Clubs

Workshops and Other Activities

Mitchell Center Seminar Series

The spring 2006 seminar series provided an introduction to current and past research initiatives on the Penobscot River. Plans are underway to remove two dams along the river which has generated renewed interest in research both pre- and post-dam removal.

Speakers included representatives from state and federal agencies who discussed Atlantic salmon restoration efforts, and water quality and biological assessment. UMaine graduate students and researchers discussed on-going research efforts on the river including migration of salmon smolts and adults, sturgeon habitat, water toxicity, and mercury cycling in sediments. The Penobscot River Synthesis Web site (http://pearl.maine.edu/windows/penobscot) provides background information and information on the various research projects continuing on the river.

The fall 2006 seminar series provided a starting point for discussion of the new Environmental Solutions Initiative (ESI). The purpose of ESI is to connect the diverse expertise and problem-solving capacity in the University of Maine System to Maine's need for more effective environmental policies and practices. For the fall semester, we brought in experienced colleagues from inside and outside Maine to help us understand how universities can transform themselves to be of greater service to society through interdisciplinary applied research and engagement with stakeholders. Invited speakers included: William Schlesinger, Dean, Nicholas School of the Environment and Earth Sciences, Duke University; Mary Cathcart and Lee Webb, Margaret Chase Smith Center for Public Policy, UMaine; David Cash, Director of Air, Energy and Waste Policy, Massachusetts Executive Office of Environmental Affairs; and Robert Kates, Distinguished Scientist, Clark University and Independent Scholar, Trenton, Maine.

Guest Lectures

The Mitchell Center hosts occasional guest lecturers as well as its regular seminar series. In 2006 we welcomed Chris O. Yoder, Research Director, Center for Applied Bioassessment and Biocriteria, Midwest Biodiversity Institute, *Continued Development of a Fish Assemblage Assessment Method for Non-Wadeable Large Rivers in Maine and New England: 2002-2005*; Jonathan Kenny, Department of Chemistry, Tufts University, *Estuarial Fingerprinting through Multi-dimensional Florescence and Multi-variant Analysis*; and Kathy Tonnessen, National Park Service Liaison to Rocky Mountain Cooperative Ecosystems Studies Unit, *Air Quality Protection for National Parks: Research and Modeling to Develop Critical Load.*

Penobscot River and Bay Institute

May-June 2006: 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 2006 over 450 students took part in the expeditions.

Volunteer River Monitoring Program

The Mitchell Center was approached in 2006 by the Maine Department of Environmental Protection to discuss the potential for establishing a Volunteer River Monitoring Program similar to Maine's successful Volunteer Lake Monitoring Program. Discussions so far have included a variety of issues including big picture issues such as the need for watershed-based volunteer monitoring, needs of stakeholders and DEP, consistency, quality, standardization, and coordination of monitoring groups, and logistical issues such as funding, data housing/storage, and office and meeting space. On-going work includes

development of a needs assessment which could be used to approach funding organizations, and obtaining a legislative resolve leading to an official report which could potentially lead to funding through the Maine legislature.

Mitchell Center website

The Mitchell Center website is updated weekly. New additions for FY06 include revised WRRI pages which provide easy access to WRRI information including requests for proposals, funded projects, and information for Principal Investigators. This will continue to expand in FY07 to provide additional resources for faculty and stakeholders. Also new to the Mitchell Center site is a listing of environmental seminars at UMaine that spans various departments including Marine Sciences, Earth Sciences, Forest Ecology, Resource Economics and Policy, Plants, Soils and Environmental Sciences, and more. Work has also begun on a complete interdisciplinary listing of environmental faculty which will be published on the Mitchell Center site. This will span not only departments and colleges at UMaine, but other universities with the University of Maine System.

PEARL – The Source for Environmental Information in Maine
Live site: www.pearl.maine.edu *Production site: www.pearlmaine.com*
PEARL continues to evolve with funding provided from a variety of sources. Maine Department of Environmental Protection continues to provide long-term support for the project.

The PEARL home page was recently redesigned to provide easier and more direct access to all aspects of PEARL including the "focus topics" pages. Two new focus topics are under development, the Maine Woods and Kenduskeag Stream sites. The Maine Woods site will host a broad spectrum of multi-disciplinary information and data about Maine's forest lands. The primary audience for this site will be educators and students from K-12 schools and colleges. The Kenduskeag Stream site will provide access to, and interpretation of, information concerning the Kenduskeag watershed, a tributary of the Penobscot River.

PEARL is also the home of the Penobscot River Synthesis, a project that aims to provide scientists, educators, and communities with needed information on Penobscot River ecology and environmental history. The site has developed as the information center for the Penobscot River Science Steering Committee. This is a partnership between the Mitchell Center, the Penobscot River Restoration Trust and the Maine Department of Environmental Protection. The committee is responsible for overseeing scientific research and monitoring related to the restoration project on the river.

Publication of a PEARL newsletter also began in August 2006. The newsletter is an on-line publication with e-mail notification to the mailing list. It includes articles on new features on PEARL along with updates of new data additions and a Q&A section. Three editions were published in FY06 (7/06, 9/06, 1/07).

We all have a stake in Maine Lakes – public brochure
Maine's 6,000 lakes attract millions of people to their shores for sustenance, enjoyment, reflection, and shelter. These activities contribute to Maine's economy and to individual incomes. These benefits, in turn, depend on the ecological health of our lakes. The goal of this brochure, which was produced in collaboration with Maine Congress of Lake Associations, is to inform policymakers and the public of the economic value of Maine lakes, what will be lost if they are not protected, and how each one of us can help preserve their benefits for future generations. The brochure was based on the findings of a 1997 WRRI funded research project, *Great Ponds Play an Integral Role in Maine's Economy*.

Maine Aquatic Biodiversity Project – public brochure
The Mitchell Center is working in partnership with The Nature Conservancy, Maine Department of Environmental Protection, and Maine Department of Inland Fisheries and Wildlife to produce a booklet based on the information published in the Maine Aquatic Biodiversity Project report. This booklet is designed to highlight information contained in the report and make it more accessible to the general public. Final publication is anticipated in summer 2007.

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. A recent Project WET workshop at the Penobscot Indian Nation reservation was attended by Scott Frazier, Executive Director of Project WET's Native Waters program. The workshop benefited from attendance of a large group of tribal educators. The Mitchell Center continues to provide communication and outreach support for Maine Project WET.

Northern Maine Children's Water Festival
The Mitchell Center is a proud sponsor and joint organizer of the Northern Maine Children's Water Festival which promotes hands on learning about water issues. This one-day event, which took place on October 10th 2006, brought together almost 800 students and their teachers. Water resource professionals from Maine and New England provided presentations and activities about water, wetlands, human health and aquatic life; there was a water trivia quiz shows hosted by local radio and television personalities, as well as activities using music and art. This experience was provided at no cost to the participants. In fact, the festival provided funding to help schools pay the cost of transportation. The goals are to teach students about the value of clean water and healthy habitats, and to provide teachers with materials and lessons that they can use for years to come. The festival is a collaborative project between Mitchell Center, Maine Department of Environmental Protection, UMaine Cooperative Extension, Americorps, and Maine Department of Education.

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. The scientific goals are:

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

The community goals are:

- Increase awareness, understanding, and interest in water resources within Ellsworth, Hancock, and Lamoine.
- 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.

The education goals are:

- 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.
- Students should develop:
    - Field sampling techniques.
    - Laboratory skills.
    - Computer competence in Excel, Word, and a GIS program.
    - Internet research capabilities.
    - Mapping abilities in both interpolation of hard copy topographic maps and interpretation of computer based topographic maps.
    - Recognize and identify specific locations by latitude and longitude on topographic maps.
    - Comprehension in terminology and function of water chemistry testing for nitrates, alkalinity, chloride, conductivity, and turbidity.
    - An understanding why conservation and commitment to a healthy environment takes an entire community.
    - Present findings to Public.

“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 seven “Waterlines…in brief” were distributed in FY06 to a mailing list of over 1,500 readers.

Kiosk Posters

The Mitchell Center, in collaboration with Maine Sea Grant and NOAA Fisheries, produced two informational posters for display at waterfront kiosks in Bucksport and Bangor. Both posters featured historical photos, maps, and information on the Penobscot River and Kenduskeag Stream watersheds and on sea-run fisheries along these waterways. This project continues to grow as collaboration with other stakeholders has produced funding to construct additional kiosks and print posters on other topics of interest throughout the Penobscot River watershed.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	0	0	0	1
Masters	3	0	0	0	3
Ph.D.	4	0	0	0	4
Post-Doc.	0	0	0	0	0
Total	8	0	0	0	8

Notable Awards and Achievements

Environmental Solutions Initiative

Together with two other UMaine faculty, Mitchell Center Director David Hart helped launch the Environmental Solutions Initiative (ESI) last fall. In the spring, Hart became the official leader of ESI. The purpose of ESI is to connect the diverse expertise and problem-solving capacity at UMaine to the State's need for more effective environmental policies and practices. To be successful, we recognize that ESI must focus simultaneously on the common goals of creating a strong economy, robust communities, and a clean environment.

Since last summer, the Mitchell Center has hosted over 30 meetings of faculty, students and external stakeholders to develop strategies and tactics for ESI. For example, the Mitchell Center invited three members of the National Academy of Sciences to present ESI seminars, and we had extensive discussions with these world-class experts during their visits. Other ESI speakers included Former Governor Angus King, Evan Richert (former director of the State Planning Office), Tom Doak (Small Woodlot Owners Association of Maine), and many other important experts and stakeholders.

E-mail updates on seminars, discussions, request for proposals and other pertinent ESI information are sent to a list of over 80 faculty members and over 50 stakeholder groups on a biweekly basis.

Penobscot River Science

The plan to remove two dams on the Penobscot River by the Penobscot River Restoration Trust is widely viewed as one of the most ambitious river restoration projects ever attempted in the world. The Mitchell Center is playing a leading role in both coordinating information on past and current research on the river and overseeing scientific research and monitoring related to the restoration project.

The Penobscot River Synthesis began in 2005 as a literature review and data inventory of past and current research in the Penobscot River and its watershed. Anticipating increased interest in the river as the Penobscot River Restoration Project moves forward, the project aims to provide scientists, educators, and communities with needed information on Penobscot River ecology and scientists, educators, and

communities with needed information on Penobscot River ecology and environmental history. Initially funded by the U.S. Geological Survey Water Resources Research Institutes program and the Atlantic Salmon Federation, the synthesis project is continuing to compile and disseminate Penobscot River information.

David Hart was asked by the Trust to lead the Science Steering Committee that serves to identify research needs and coordinate research activities that will guide this unprecedented project. Catherine Schmitt has acted as coordinator and the Mitchell Center as host for numerous meetings related to this project. The Center recently coordinated and managed the first request for research proposals that will provide new funding to a number of UMaine faculty. The funding for this research will come from NOAA and The Nature Conservancy.

The Mitchell Center's spring 2006 seminar series provided an introduction to current and past research initiatives on the Penobscot River. Speakers included representatives from state and federal agencies who discussed Atlantic salmon restoration efforts, and water quality and biological assessment. UMaine graduate students and researchers discussed on-going research efforts on the river including migration of salmon smolts and adults, sturgeon habitat, water toxicity, and mercury cycling in sediments.

GET WET!

GET WET! developed from a research project that studied the effects of gravel mining on drinking water supplies. There is a growing concern that many communities will not have the water resources to support anticipated population growth. Sand and gravel deposits have the capacity to provide large quantities of water suitable for drinking. Mining sand and gravel deposits may degrade water quality or actually remove the aquifer.

If towns are to manage their natural resources wisely, information is needed to understand the effects of mining on water quality. It was clear those local communities where there is shared use of sand and gravel deposits needed a way to create a long-term groundwater quality database. Involving students and community members in this process provide an opportunity to increase local participation and understanding of the issues.

We have established an educational curriculum where local students conduct testing of well water from local private wells to develop town-centered monitoring that can become the foundation of long-term monitoring programs. The curriculum includes public presentations or workshops on the natural history and value of sand and gravel deposits and establishment of a data repository at towns and at the University of Maine to maintain monitoring data.

Portable laboratory test kits are used to provide reliable and accurate measurements suitable for student use. The curriculum includes opportunities to teach students about local natural history and to draw the connection between land use and water quality. Students present a public summary of their research that includes a discussion of the multiple uses of sand and gravel deposits. Student data is added to the UMaine's growing database of groundwater quality data that is housed on PEARL (www.pearl.maine.edu).

Mitchell Center Graduates

Four Mitchell Center students graduated with Master's degrees in Ecology and Environmental Science with an option in Water Resources. Graduating were Melinda Diehl, Kirsten Ness, Lisa Fretwell and Teresa Thornton. Research topics for these students included using stream chemistry to evaluate experimental acidification and natural recovery in the paired catchments; temporal and spatial relationship between phosphorus and nitrogen concentrations, algal growth, and nutrient sources; and the effects of shoreline development on lake littoral and riparian habitats.

Special Issue of the Journal Environmental Monitoring and Assessment

In February 2006, Sarah Nelson of the Mitchell Center and Steve Kahl, Plymouth State University submitted a group of eleven manuscripts to become a special issue of the journal Environmental Monitoring and Assessment. Nelson and Kahl serve as guest editors for the special issue. Titled Mercury and nitrogen biogeochemistry in paired watershed studies at Acadia National Park, Maine, USA, the special issue was published in April 2007. The manuscripts report on research at paired gauged watersheds at Acadia National Park, studied by Mitchell Center (Ken Johnson, Sarah Nelson, Steve Kahl, John Peckenham) and UMaine (Bruce Wiersma, Molly Schauffler) researchers since 1998. In addition, papers by Mitchell Center researcher John Peckenham and US Geological Survey researcher Martha Nielsen put the small watershed results in an island-wide context; an introduction by Kathy Tonnessen and David Manski of the National Park Service lends a policy and management perspective. A set of papers on mercury in Acadia's biota by UMaine researchers Michael Bank and Jerry Longcore (USGS) include a review of previously unpublished results from various UMaine studies, and new information indicating that the mercury problem is Acadia is significant for wildlife there (see also M. Edgecomb, Bangor Daily News, Jan. 5, 2004).

The USGS base grant provided a basis for the Senator George J. Mitchell Center to secure other research funding. The following projects were funded in 2006:

Title: PEARL (on-going)
Investigator:Vaux
Agency: Maine Department of Environmental Protection

Title: Do water sampling techniques affect aluminum speciation? (on-going)
Investigators: Johnson/Nelson
Agency: Atlantic Salmon Commission

Title: Closing the loop on hydrologic and mass balances for a temperate forested park
Investigator: Nelson
Agency: Canon National Parks Science Scholarship

Title: A hydrogeomorphic lake classification system for refining lake assessment at multiple spatial scales (on-going)
Investigators: Webster, Vaux, Bell, Bacon
Agency: EPA

Title: Can Gravel Mining and Water Supply Wells Coexist? (on-going)
Investigator: Peckenham
Agency: Island Foundation

Title: SWWAT Source Water Analysis and Warning Technology (on-going)
Investigator: Peckenham
Agency: EPA

Title: Penobscot River Synthesis (on-going)
Investigator: Schmitt
Agency: French Foundation

Title: The Impact of Vehicle Traffic on Water Quality in Acadia National Park
Investigator: Peckenham
Agency: National Park Service

Title: Acidity partitioning model development
Investigator: Johnson
Agency: Atlantic Salmon Commission, 2006

Title: Acadia National Park Watershed Assessment
Invesitgator: Vaux
Agency: National Park Service

Title: Kenduskeag Salmon Recovery Project
Investigator: Vaux
Agency: National Fish and Wildlife Foundation

Title: Maine Woods Online: An Information Sharing Forum for Educators and Students
Investigator: Vaux
Agency: Maine Forest Bioproducts Research Project

Title: Penobscot River Science Steering Committee Coordination
Investigator: Schmitt
Agency: Maine Department of Environmental Protection

Title: Penobscot River Synthesis
Investigator: Schmitt
Agency: Norcross Wildlife Foundation

Title: How much is enough? Developing a citizen-based monitoring plan for mercury in gauged watershed streams at Acadia National Park
Investigator: Sarah Nelson
Agency: L.L. Bean and Acadia Partners

Publications from Prior Projects