Water Resources Research Center
Annual Technical Report
FY 2005

Introduction

This report covers the period March 1, 2005 to February 28, 2006, the 40th year of the Massachusetts Water Resources Research Center (WRRC). The Center was under the direction of Dr. Sarah Dorner, who holds a joint appointment as Director of the WRRC and as Research Assistant Professor in the Department of Public Health at the University of Massachusetts Amherst.

In October 2005, the MA WRRC organized the Third Annual WRRC Conference Research to Practice: Science for Sustainable Water Resources. The WRRC conference is now firmly established as a highly regarded meeting for scientists and water resources professionals in Massachusetts and New England.

Two innovative research projects were completed this year: Potential Movement of Pesticides Related with Dissolved Organic Matter from Organic Fertilizer Application on Turf by Dr. Baoshan Xing of UMass Amherst Department of Plant and Soil Sciences, and Copper Removal by Biofilms, by Dr. Xiaoqi Zhang of UMass Lowell Department of Civil and Environmental Engineering.

Dr. Stephen Mabee of UMass Amherst Department of Geosciences continued work on a 104G USGS grant to look at A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management.

Dr. Sarah Dorner headed a one-year project in the Public Health Department on Sources of E. coli during Wet-Weather Events. At the University of Massachusetts Dartmouth, Dr. Yuegang Zuo of the Chemistry and Biochemistry Department began a two-year project on Monitoring Estrogenic Hormones Undesired Fish Contraceptives, and Investigating Their Sources, Transportation and Fate in Buzzards Bay, Massachusetts. Finally, a graduate student grant was awarded to Brian Tavernia of Tufts University Biology Department to study Cryptic Marsh Birds as Bioindicators of Wetland Health.

Other projects conducted at WRRC include the Massachusetts Water Watch Partnership, the Acid Rain Monitoring Project, and continued collaboration with UMass Extension on a stream continuity project. This was the second year of cooperation with the Mechanical Engineering Department at UMass Amherst on a Non-Point Source grant to develop a Clearinghouse for innovative stormwater Best Management Practices in Massachusetts. The History and the Computer Science Departments were WRRCs partners on two new projects looking at Watershed Community as a new way to teach environmental science to the public.

Research Program

A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management

Basic Information

Title:	A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management
Project Number:	2003MA19G
Start Date:	9/30/2003
End Date:	9/29/2007
Funding Source:	104G
Congressional District:	1st District of MA
Research Category:	Ground-water Flow and Transport
Focus Category:	Water Supply, Groundwater, Water Quantity
Descriptors:	fracture characterization, domain analysis, well yield, fractured rock aquifers, groundwater availability, groundwater mapping, borehole geophysics
Principal Investigators:	Stephen B. Mabee, Michele Cooke

Publication

1. Manda, A.K., 2005, Characterizing the fractured bedrock aquifer of the Nashoba Terrane, Massachusetts, Mass. Water Resources Research Center/UMass Extension 3rd Annual Conference, Research to Practice: Science for Sustainable Water Resources, Amherst (Poster).
2. Manda, A.K., Mabee, S.M.B., and Hubbs, S., 2005, Field Mapping and Fracture Characterization Techniques Predict Groundwater Preferential Flow Paths in Fractured Bedrock Aquifers, Nashoba Terrane, MA, American Geophysical Union Annual Meeting, San Francisco, Abstract H23E-1477 (Poster), published on CD.

A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management- June 2006 Annual Report

Stephen B. Mabee

Project Description

Problem Statement

The use of fractured-bedrock aquifers to meet private, public and commercial water supply needs is increasing in the New England region. Municipalities and water suppliers are finding it increasingly difficult to locate and develop water supplies in overburden aquifers because of contamination and a lack of suitable sites. In addition, recent droughts in the northeast have forced many communities and homeowners to drill new wells. As a result, water suppliers are going deeper into bedrock aquifers. Yet information on the factors that influence the availability and recharge characteristics of fractured bedrock aquifers in highly deformed crystalline metamorphic rocks is limited.

The availability of water in fractured rock aquifers is particularly critical in New England because growth and development along the coast, major transportation corridors and in rural communities adjacent to large metropolitan areas is rampant. For example, the I-495 corridor in Massachusetts, a circumferential highway 30 miles west of Boston, has become the focus of recent growth. Professional office buildings, research and development parks associated with the computer industry, warehouses and light industry are springing up along this corridor, as are housing and condominium developments. Municipalities and water suppliers are simply unprepared for the onslaught of development and need help in understanding the complex dynamics of the ground water system.

Sustaining and managing ground water resources in fractured bedrock require an evaluation of 1) the availability of water, 2) the source and vulnerability of recharge to water supply wells and 3) the impact of water withdrawals from the bedrock on streams, wetlands and unconsolidated aquifer systems that overlie the bedrock. These evaluations all require basic information on the physical characteristics of the ground water system.

Objectives

The objectives of this project are to gather regional bedrock characteristics that relate to the occurrence and movement of ground water in bedrock and use this information to begin constructing regional conceptual models of the fractured-rock aquifers in the Nashoba terrane in Massachusetts. The approach utilizes existing information augmented by the collection of low-cost field data to develop regional conceptual models of the ground water flow system. Water managers can then use these conceptual models as an initial framework for formulating an understanding of bedrock flow behavior and recharge characteristics.

Specific tasks of this project involve: 1) Fracture Characterization and Domain Analysis - collection and synthesis of fracture characterization data over the region and mapping of the spatial distribution (domain analysis) of fracture sets and their characteristics, 2) Compilation and Analysis of Existing Well Data - compilation and statistical analysis, including variography, of available well data to link spatial continuity of well yields to characteristics of the fractured rock system, 3) Borehole Geophysics - collection of optical and acoustic televiewer data from selected boreholes to verify sheeting joints, 4) Compilation of Regional Litho-Group Map - development of a mapping classification system that uses the notion of "litho groups" to characterize bedrock units in terms of their fracture characteristics, physical properties and geologic setting (eg., overburden type and thickness) and 5) Conceptual Model - preparation of a qualitative conceptual model of ground water flow behavior in each litho group category.

Relationship of Project to USGS and Other Activities

This project is part of a much larger, more comprehensive study being conducted by the USGS WRD Northborough office on the Geohydrology of the Nashoba Terrain, Massachusetts. This larger scale project involves the collection of data at three scales: regional, quadrangle and the local well-field scale. Recent work by the USGS in Connecticut and New Hampshire indicates that an understanding of ground water occurrence and movement in fractured rock aquifers can be made by combining the results of 1) fracture, geologic, well, and geophysical analyses performed at the regional level, 2) detailed mapping of bedrock lithology and physical characteristics that affect water occurrence and flow at the quadrangle scale, and 3) hydrogeologic and geophysical investigations at the well-field scale. This larger scale project is a joint effort that involves the participation of USGS scientists from the Water Resources Discipline, USGS mappers from the BRASS (Bedrock Regional Aquifer Systematics Study) program, the Office of the Massachusetts State Geologist, and University of Massachusetts scientists (this project). Table 1 describes the tasks that each agency will perform and shows how the work will be coordinated.

Table 1. Coordination Plan and Approximate Timetable

Task	Activity	Timetable	Responsible Party
Existing Data (Regional Scale)	Base map	2003	USGS[1]
	Geologic map	2003	USGS
	Imagery	2003	USGS
	Fracture data/analysis	completed	This Project[2]
	Existing well data/analysis	completed	This Project
	Add'l well data in field	underway	This Project/USGS
	Borehole fracture data	2005	This Project/USGS
	Litho-group map	underway	This Project
Geologic & Fracture Data (Quadrangle Scale)	Map Quad #1-Grafton	completed	USGS BRASS[3]
	Map Quad #2-Marlboro	completed	State Geologist[4]
	Map Quad #3-Nashua S.	underway	USGS BRASS[3]
	Map Quad #4-Hudson	completed	State Geologist[4]
	Map Quad #5-Ayer	completed	State Geologist[4]

	Map Quad #6-Milford	underway	
Conceptual Model Devel.		underway	This Project/USGS
Test and Verify Model (Well Field Scale)		2006	This Project/USGS
Prepare and Publish Reports		2006/2007	This Project/USGS

[1] Start date of USGS cooperative project is March 2003, Bruce Hansen, USGS
[2] Start date of this project is September 30, 2004 (no cost extension granted)
[3] USGS BRASS = Bedrock Regional Aquifer Systematics Study project, Greg Walsh, USGS, began mapping in summer 2004; started Nashua South quadrangle in 2006
[4] State Geologist – Mapping funded by the STATEMAP component of the National Cooperative Geologic Mapping Program, Marlboro completed in June 2004, Hudson preliminary map completed in June 2005, Ayer quadrangle completed 2006, Milford underway summer 2006.

Work Accomplished on *This Project* in Past Year

Alex Manda began working on this project in September 2004. Alex received his undergraduate degree in geology from Cardiff University in 2001 and finished his M.S. degree at Florida International University in August 2004. He passed his Ph.D. comprehensive exams at the University of Massachusetts in February 2005 and has completed his dissertation proposition.

Work completed during the period February 28, 2005 to June 30, 2006 includes:

1. Conducted fracture characterization field work and visited 79 outcrops over a two and a half month period and collected over 4000 brittle fracture measurements (Task 1).
2. Analyze and summarize fracture characterization data (Task 1).
3. Analyze GWSI well data of terrane including performing variography (Task 2).
4. Begin constructing hydro-structural domain map of the terrane from the field data (Task 4).
5. Currently building discrete fracture network models of individual outcrops and assigning hydraulic conductivity values to several domains for testing against well-field scale pumping test and borehole geophysical data.
6. Working with the USGS to acquire additional borehole geophysical data.

The final year will be spent performing numerical modeling of the conceptual models developed from the hydro-structural domains and field fracture data. The models will be calibrated against well-field scale hydraulic data.

Work Accomplished by Collaborators (Table 1)

USGS – The USGS WRD Northborough office was not funded in the past year for this project. However, new funds are now available and the USGS is currently developing a revised scope of services to continue this work into the next fiscal year. A meeting was held with the USGS, University of Massachusetts and the Massachusetts Department of Environmental Protection to determine the data needs for the project.

Office of the Massachusetts State Geologist – The office of the Massachusetts State Geologist has contributed in the following way using funds supplied by the National Cooperative Geologic Mapping STATEMAP program:

1. A preliminary bedrock geologic map and a fracture characterization map have been prepared for the Ayer quadrangle. These maps provide detailed lithologic and fracture characterization data as well as information on the distribution of permeable overburden deposits at the quadrangle scale. These data will be used as a test for the regional scale and quadrangle scale hydro-structural domain maps to be prepared under this project. We now have new bedrock and fracture characterization maps for three quadrangles that provide a north south transect across the Nashoba terrane.
2. In addition, using funds from the EDMAP component of the National Cooperative Geologic Mapping Program, we have new bedrock and fracture characterization maps of the Shrewsbury and Maynard quadrangles, which nearly completes an east-west transect across the Nashoba terrane.
3. A well database consisting of over 1200 wells has been assembled for the Ayer quadrangle.
4. During the summer of 2006, bedrock and fracture characterization data will be collected for the Milford quadrangle. A well database is also being prepared for the towns located in this quadrangle.

USGS BRASS Program – Greg Walsh from the USGS BRASS program completed bedrock and fracture mapping in the Grafton quadrangle. This will provide detailed lithologic and fracture characterization data for another quadrangle within the project area. Greg Walsh will be mapping the Nashua South quadrangle during 2006, which is outside the Nashoba terrane.

Summary of Results

The following is a description of results, achievements and goals related to this project. The specific objective is first stated before a description of the status of that objective is given. Highlighted below are both the goals that have been achieved and those that are till pending.

1) Fracture Characterization and Domain Analysis - collection and synthesis of fracture characterization data over the region and mapping of the spatial distribution (domain analysis) of fracture sets and their characteristics.

Fracture characterization data was collected from 79 outcrops located in the Nashoba Terrane (Fig. 1) during the summer of 2005. The total number of fracture measurements collected from all the outcrops in the terrane was 4024. Information collected included rock type, fracture orientation, fracture trace length, fracture spacing, fracture termination and mineralization data. The information was compiled and manipulated in a GIS where datalayers showing the spatial distribution of the outcrops and accompanying fracture characterization information were created.

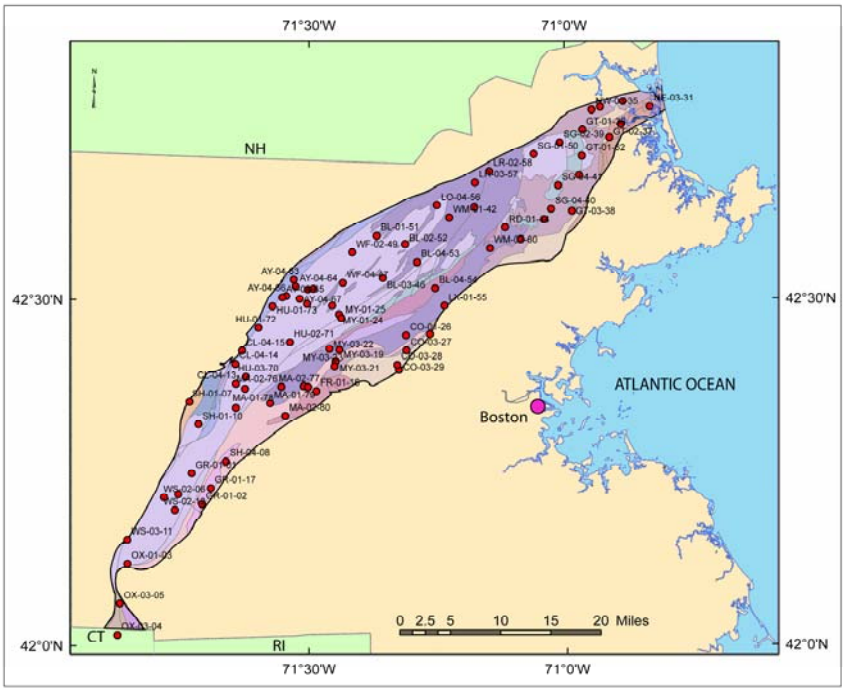

Figure 1. Location map of the Nashoba Terrane in eastern Massachusetts showing the distribution of outcrops (circles with outcrop ID) throughout the terrane.

Data analysis revealed that there were five types of discontinuities in the Nashoba Terrane: non-horizontal joints, sub-horizontal joints (sheeting joints), faults, partings parallel to foliation, and veins. Outcrop scale faults and veins comprised less than 3% of the total number of fractures collected in the terrane. Non-horizontal joints were shown to be pervasive across the entire terrane whereas horizontal joints and partings parallel to foliation were only strongly developed at select outcrops.

Preliminary results show that the degree of development of partings parallel to foliation varied as a function of rock type. It appeared that partings parallel to foliation were more strongly developed in the Marlboro Formation than the Nashoba Formation. An equal area plot shows one cluster of steeply dipping partings parallel to foliation (> 60°) with a mean orientation of about 036/60 NW (Fig. 2). However, an evaluation of an azimuth versus traverse distance plot shows that there isn't one particular cluster across the entire terrane, but that the partings parallel to foliation rotate clockwise from about 10° in the southwestern end of the terrane to about 60° at the northeast end. This rotation seems to follow the trend of the axis of the Nashoba terrane, which is a result of regional deformation.

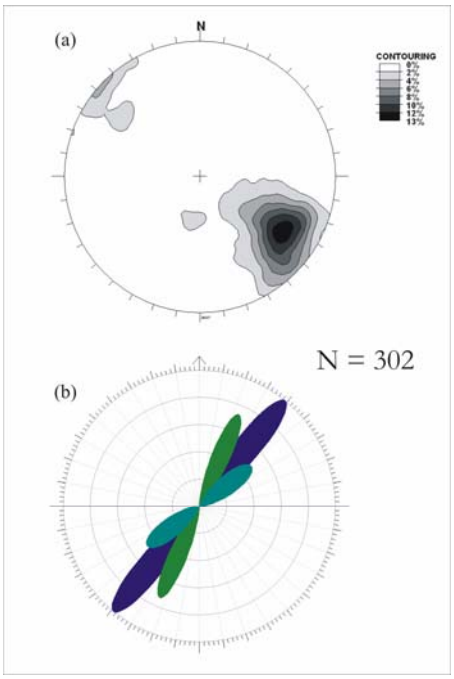

Figure 2. (a) Equal area net representing partings parallel to foliation observed at outcrops in the terrane. (b) Rose diagram showing the trend of the partings parallel to foliation depicted in (a)

Non horizontal joints dipping at 60° and greater were observed to cluster in at least 10 major sets. There was no systematic variation of fracture orientation of the non-horizontal joints from southwest to northeast. In fact, the distribution of joint orientation seems to be random at the regional scale in the Nashoba Terrane. The major joint sets in the terrane include the 108°, 138°, and 124° as shown in Table 1.

Table 1. Fracture spacing for fracture sets in the Nashoba Terrane

Set	n	Mean	Std Dev	Median	Min	Max
108 degrees	217	0.74	1.09	0.40	0.01	8.00
138 degrees	177	0.53	0.61	0.30	0.01	3.00
124 degrees	180	0.73	1.02	0.40	0.01	10.00
036 degrees	288	0.40	0.57	0.20	0.01	5.00
154 degrees	142	0.55	0.80	0.30	0.01	7.50
004 degrees	123	0.48	0.75	0.25	0.01	6.00
021 degrees	178	0.56	0.86	0.29	0.01	5.00
054 degrees	256	0.37	0.46	0.20	0.01	3.00
082 degrees	202	0.53	1.01	0.25	0.01	10.00
169 degrees	115	0.52	0.62	0.30	0.01	3.00
All Fractures	2097	0.55	0.86	0.30	0.01	15.00
Sub-Horizontal	247	0.74	0.94	0.50	0.03	10.00

All measurement (except n) are in units of m

On average, horizontal joints displayed longer trace lengths and wider fracture spacing than non-horizontal fractures. The shorter trace lengths observed in the non-horizontal fractures could be a function of the size of the vertical section of an outcrop that is exposed. Truncation errors are therefore more prevalent in trace length statistics of non-horizontal fractures than horizontal fractures.

Non-horizontal joint sets with the widest spacing between fractures were the 108°, 004°, and 154° joint sets. Although these sets had the widest fracture spacings, the median spacings were all less than 0.5 m. The median spacing for sub-horizontal joints is 0.5 m (Table 1).

In terms of termination, sub-horizontal joints tended to abut against other fractures whereas the non-horizontal joint sets were predominantly through-going fractures.

2) Compilation and Analysis of Existing Well Data - compilation and statistical analysis, including variography, of available well data to link spatial continuity of well yields to characteristics of the fractured rock system.

Geostatistical analysis (variography) was conducted on the United States Geological Survey-Ground Water Site Inventory (USGS GWSI) data derived from the Nashoba Terrane. Results from the regional analysis suggested that the density of wells in the GWSI database was insufficient to adequately perform variography. There were ~580 wells in a 630 square mile region giving a well density of ~0.9 wells per square mile. Subsequently, a smaller region with a large number of wells culled from well completion reports was used to test the variogram method. This dataset provided 530 wells in a 110 square mile region encompassing the Hudson and Marlboro quadrangles thereby increasing the well density by over fivefold to 4.8 wells per square mile.

Cross validation results from the variogram analysis show that the match between predicted and observed measurements of well yield is poor. The major conclusions reached after conducting geostatistics on this new data set were that either geostatistics is a poor indicator of the link between spatial continuity of well yield and fracture characteristics of the bedrock system, or the measure of aquifer productivity (well yield) had inherent errors.

3) Borehole Geophysics - collection of optical and acoustic televiewer data from selected boreholes to verify sheeting joints.

Borehole geophysical data is currently being sought from the USGS for three locations in Hudson, Acton and Maynard. Pumping test information from the three sites has already been obtained and will be evaluated together with the borehole geophysical data to determine the vertical distribution of fractures in boreholes.

4) Compilation of Regional Litho-Group Map - development of a mapping classification system that uses the notion of "litho groups" to characterize bedrock units in terms of their fracture characteristics, physical properties and geologic setting (e.g., overburden type and thickness).

Another term, 'hydrostructural domain' will be used in place of 'litho group' to describe assemblages of rocks that have similar physical properties and hence similar hydraulic characteristics. Major criteria for determining hydrostructural domains are rock type, number and distribution of fracture sets, type of fractures present or absent, degree of fracture development, fracture spacing and nature of fracture termination. A preliminary hydrostructural domain map was created based on only four of the above criteria (rock type, number and distribution of fracture sets, type of fractures present or absent, degree of fracture development) (Fig. 3). To derive a more robust measure of the hydraulic character of an aquifer from its physical characteristics, two other measures were chosen to be part of the criteria for an improved hydrostructural domain map (fracture spacing and nature of fracture termination). We are currently conducting research to adequately incorporate all the criteria in determining hydrostructural domains for the improved map.

5) Conceptual Model - preparation of a qualitative conceptual model of ground water flow behavior in each litho group category.

Field data and hydrostructural domains will be used to establish a conceptual model of the groundwater flow regime in the Nashoba Terrane. Physical characteristics observed in the field can be used to qualitatively describe the ground water flow behavior of fractured media. The degree of fracture development, presence or absence of conducting fractures and other information can be used to assess the qualitative differences between units of rocks with varying physical features. Regions with units of rocks that have only one fracture set orientation will exhibit an anisotropic flow regime trending parallel to the strike of the set. On the other hand, units with two or more fracture sets will display less anisotropy because the water will flow in more than one dominant direction.

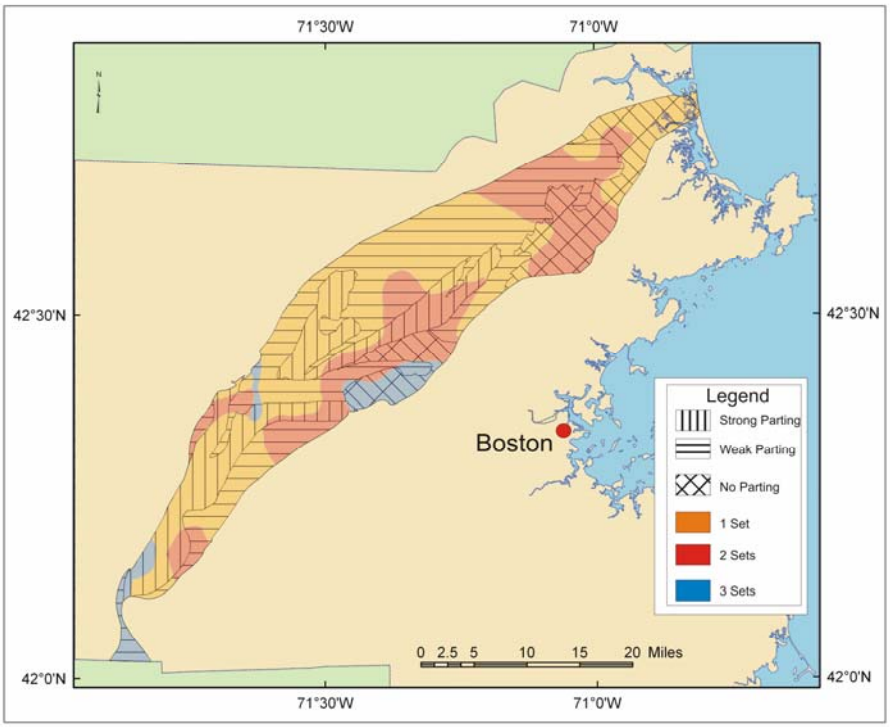

Figure 3. Preliminary hydrostructural domain map of the Nashoba Terrane.

Current and future research will also focus on conducting numerical simulations of discrete fracture networks to assess the hydraulic properties of fractured bedrock media. These simulations will use fracture characterization information that was collected in the Nashoba Terrane to derive quantitative measures of the hydraulic properties of particular domains. Currently lacking in studies of fractured media is the link between qualitative assessments and quantitative properties of these particular units. Our aim is to use the fracture characterization data that has been collected thus far to derive not only qualitative assessments of hydrostrucural domains but also to assign quantitative measures of particular hydraulic properties to these units. Decision makers will thus be provided with a robust measure of fractured media properties that they can rely on to manage water resources more effectively.

Some results of the ongoing research described above and in a previous report were presented at the Massachusetts Water Resources Research Center Conference in fall 2005 and the American Geophysical Union biennial meeting in San Francisco (Manda 2005: Manda et al 2005).

Cryptic Marsh Birds as Bioindicators of Wetland Health

Basic Information

Title:	Cryptic Marsh Birds as Bioindicators of Wetland Health
Project Number:	2005MA45B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	7th MA
Research Category:	Biological Sciences
Focus Category:	Conservation, Ecology, Wetlands
Descriptors:	
Principal Investigators:	Brian G. Tavernia, J. Michael Reed

Publication

1. Tavernia B., S. Melvin. and J.M. Reed, 2006 Local and Landscape-level Effects on Marsh Bird Distributions in a Developing Landscape. Conserving Birds in Human-Dominated Landscapes, symposium sponsored by American Museum of Natural History's Center for Biodiversity and Conservation, New York, NY. (Poster)

Project Summary:

Local and Landscape-level Effects on Marsh Bird Distributions in a Developing Landscape

Brian G. Tavernia, Scott Melvin, & J. Michael Reed

Abstract

Extensive wetland loss associated with agriculture and urban sprawl has placed many marsh-dependent birds at risk, including several species of conservation concern at state and federal levels. Assessing effects of habitat loss requires effective monitoring. Many marsh species, however, are poorly covered by common survey methods, and rails in particular are behaviorally cryptic. During 2005, we used visual surveys and call playback to do repeated surveys for breeding marsh birds in 44 wetlands in central and eastern Massachusetts. Wetlands were in habitat matrices ranging from urban to rural settings. We analyzed the relationships between measured local and landscape features and species richness, as well as occupancy by the most common rail species, the Virginia Rail (*Rallus limicola*). Local habitat variables included areas of wetland, open water, and cover of different types of emergent vegetation. At the landscape level we quantified features thought to affect wetland occupancy by these species, including land use, road cover, and human census size at 8 spatial scales (50 m through 4 km). We found both local and landscape variables associated with species richness (r2 =0.84) and occupancy by Virginia Rails (r2 = 0.46). Important landscape-level variables associated with species richness included a variety of urban associations, including census size and road cover. These factors had effects at larger spatial scales (1-4 km); urban measures negatively associated with human census size (e.g., industrial land) were positively associated with species richness. Virginia Rail occupancy was driven by area of water smartweed (*Polygonum punctatum*), and wetland cover measures (at 50 m and 1 km levels). One insight from this analysis is that some urban measures (people, roads) are negatively associated with others (industrial, commercial), and should be distinguished when assessing effects of "urbanization".

Introduction

Wetlands are biologically diverse habitats that are under immediate threat from agriculture expansion and suburban sprawl. In some states of the U.S., >80% of historic wetlands have vanished. An important factor in the loss, degradation, and fragmentation wetland habitat is urban and suburban sprawl. These changes in landscapes are thought to be the most important threat to cryptic marsh birds (e.g. rails, bitterns, and grebes), several of which are of conservation concern at state and federal levels. Unfortunately, cryptic marsh birds are a poorly known group, so it is difficult to quantify the full impact of wetland loss and alteration.

Our goal was to determine the local and landscape variables associated with the richness and distribution of cryptic marsh bird species. Research has shown that landscape features as much as 4 km from a wetland can influence wetland chemistry. Therefore, it is reasonable to predict that large-scale landscape level characteristics might influence the suitability of wetland habitat for cryptic marsh birds.

Our specific objectives were to: (1) use playback surveys to determine the presence or absence of cryptic marsh birds in 44 MA wetland sites; (2) relate cryptic marsh species richness to local and landscape level information gathered for each site; and (3) determine the influence of local and landscape characteristics on wetland occupancy by the most common rail species in our study area, the Virginia Rail (*Rallus limicola*).

Methods

From May to July of 2005, we used playback surveys to gather occupancy data for cryptic marsh birds in 44 freshwater emergent wetlands in central and eastern Massachusetts. Target species were the American Bittern (*Botaurus lentiginosus*), Least Bittern (*Ixobrychus exilus*), Pied-billed Grebe (*Podilymbus podiceps*), King Rail (*Rallus elegans*), Virginia Rail (*Rallus limicola*), Common Moorhen (*Gallinula chloropus*), Sora (*Porzana carolina*), Great Blue Heron (*Ardea herodias)*, and Green Heron (*Butorides virescens*). As these species are difficult to detect, playback surveys used recorded vocalizations to elicit responses from birds. Sites were surveyed on three occasions to ensure a ≥ 90% chance of detecting species if they were present. The number of species detected was summed to obtain a measure of species richness for each site. Some of the sites were surveyed by the USFWS, who used the same survey protocol.

During July, the areas of different vegetation types and open water in each site were visually estimated. ArcMap 9.0 was then used to determine the average local habitat conditions within 50 m and 100 m of established survey points in each of the wetland sites. Local factors considered included wetland area, aquatic bed vegetation, open water, cattail, purple loosestrife, shrub, swamp loosestrife, water smartweed, and fine-leaved emergents.

Landscape level information was gathered for each of the sites using ArcMap 9.0 at 8 spatial scales (50 m - 4 km). Specifically, we measured the area of several different land use types: agriculture, forest, wetland, water bodies, and developed land (e.g. commercial and industrial). The number of people and road length at each spatial scale were also measured. Landscape information was obtained from MassGIS (www.mass.gov/mgis).

Species richness was related to local and landscape factors using multiple regression. Logistic regression was used to relate the occupancy of Virginia Rails to local and landscape characteristics of each site. Statistical analyses were carried out in SAS 9.1.

Results

We found significant relationships between local and landscape measures and waterbird species richness and occupancy by Virginia rails.

Results of species richness (multiple regression)	
Source	df
Model	10
Error	33
Corrected Total	43
p-value = <0.01	r^2 = 0.84

Independent variables in Model (Type III values)		
Variable	Effect	p-value
Fine-leaved emergents (50 m)	(-)	0.02
Cattail (100 m)	(+)	<0.01
Agricultural land (50 m)	(+)	<0.01
Wetland (50 m)	(+)	<0.01
Wetland (1 km)	(+)	<0.01
Water bodies (1 km)	(+)	<0.01
Developed (1 km)	(+)	<0.01
Developed (2 km)	(+)	0.03
Major Roads (3 km)	(-)	0.05
Major Roads (4 km)	(-)	<0.01

Virginia Rail occupancy (logistic regression)	
Variable	Effect
Water smartweed (50 m)	(+)
Wetland (50 m)	(+)
Water bodies (1 km)	(+)
p-value = <0.05	r^2 = 0.46

Discussion

We found local wetland characteristics and features of the surrounding landscape to be significantly related to cryptic marsh bird species richness and wetland occupancy by Virginia Rails. Many of the factors associated with species richness were measures of urbanization. Increasing road length at larger spatial scales was negatively correlated with species richness. Roads are thought to negatively affect wetlands and wetland wildlife in several ways. For example, roads can increase the amount of and alter the chemical composition of runoff into wetlands as well as allow humans greater access. Interestingly, increasing amounts of developed land (e.g. industrial land) were positively associated with species richness. This could be because developed land is negatively

correlated with other measures of urbanization, e.g. road density or human population size.

While not directly related to measures of urbanization, Virginia Rail occupancy was, in part, driven by measures of wetland cover at the landscape scale. This influence could be due to rails cueing in on water body rich areas because they possess a fairly broad and diverse resource base. Continued development of the surrounding landscapes would result in increasing loss of wetland habitat decreasing the suitability of many areas for Virginia Rails.

The effects of urbanization are generally thought to be correlated, and associated with negative effects on native biodiversity. For example, the number of people and road cover tend to co-occur. The presence of people also increases other problems, such has feral cat numbers. However, some urban measures, such as industrial land and commercial property cover, are associated with lower human numbers and road density. So, it would be valuable to think of urbanization in terms of specific mechanisms that might impact – or favor (compared to other human development) – native biodiversity.

Our results lend support to the idea that continuing development and urbanization of landscapes will be detrimental to cryptic marsh bird species. Future efforts to conserve these species will need to account for the potential impact of continuing landscape development.

Acknowledgements

Funding: Massachusetts Environmental Trust, USGS through Massachusetts Water Resources Research Center, Nuttall Ornithological Club; *Data*: U.S. Fish and Wildlife Service; *Analyses*: Yelena Ogneva-Himmelberger

Use of WRRC Funds:

WRRC funds were used to pay the travel expenses of an undergraduate research assistant.

Presentations:

- Tavernia B., S. Melvin. and J.M. Reed. 2006. Local and Landscape-level Effects on Marsh Bird Distributions in a Developing Landscape. Conserving Birds in Human-Dominated Landscapes, symposium sponsored by American Museum of Natural History's Center for Biodiversity and Conservation, New York, NY. (Poster)

Additional Funding:

No additional funding has been obtained to date.

Monitoring Estrogenic Hormones Undesired Fish Contraceptives, and

Basic Information

Title:	Monitoring Estrogenic Hormones Undesired Fish Contraceptives, and
Project Number:	2005MA47B
Start Date:	3/1/2005
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	3rd Massachusetts
Research Category:	Water Quality
Focus Category:	Water Quality, Toxic Substances, Geochemical Processes
Descriptors:	
Principal Investigators:	Yuegang Zuo

Publication

1. Zuo, Yuegang, Kai Zhang and Yiwei Deng, 2006, Occurrence and photochemical degradation of 17α-ethinylestradiol in Acushnet river estuary, Chemosphere (63), 1583-1590.
2. Zuo, Yuegang and Kai Zhang, 2005, Discussion: Suitability of N,O-bis(trimethylsilyl)trifluoroacetamide as derivatization reagent for the determination of the estrogens estrone and 17 α-ethinylestradiol by gas chromatography-mass spectrometry, J. of Chromatogr. (A 1095), 201-202.
3. Zhang, Kai and Yuegang Zuo, 2005, Pitfalls and solution for simultaneous determination of estrone and 17α-ethinylestradiol by gas chromatography mass spectrometry after derivatization with N,O-bis(trimethylsilyl)trifluoroacetamide. Anal. Chim. Acta (554), 190-196.

2006 Annual Report for Water Resources Research Center/the USGS Water Resources Program Project

Monitoring Estrogenic Hormones – Undesired Fish Contraceptives, and Investigating Their Sources, Transportation and Fate in Buzzards Bay, Massachusetts

Project Activities:

Estrogenic hormones and related synthetic steroid compounds, such as those used in contraceptive pills, have been shown to be present in the aquatic environment, mainly as a result of inefficient removal in wastewater-treatment plants. The concentrations of the compounds, although very low (sub-ng to a few ng/L), are sufficient to induce estrogenic responses and alter the normal reproduction and development of wildlife organisms. Of estrogenic compounds, synthetic contraceptive steroids, such as 17α-ethinylestradiol (EE2), are found to be the most potent endocrine disruptor. It can cause feminization of male fish even at extremely low concentrations (e.g. 0.1 ng/L). The Buzzards Bay receives stormwater runoff and effluent from wastewater treatment facilities of New Bedford, Fairhaven, Fall River and other surrounding towns. This leads to direct input of many different classes of pollutants, including endocrine-disrupting estrogenic hormones, through the sewage effluents and industrial wastewater. The combination of these estrogenic compounds and other pollutants can adversely affect plankton and fish, and could be related to the decline in lobster abundance in Buzzards Bay. The objectives of this research project are (1) to develop an SPE-GC-MS analytical method for the separation and quantitation of estrogenic hormones: estrone, 17β-estradiol, 17α-ethinylestradiol and mestranol; (2) to employ the analytical methods developed in this project to monitor estrogenic hormones: estrone, 17β-estradiol, 17α-ethinylestradiol and mestranol in New Bedford Harbor and Buzzards Bay Water; (3) to assess the microbial and photochemical fate of estrogenic hormones in the Buzzards Bay; (4) To train graduate and undergraduate students to use the techniques developed in this project to monitor and protect our aquatic environment.

In the first year of this project, our research has been focused on developing a Solid-Phase Extraction (SPE) GC-MS analytical method for the separation and quantitation of estrogenic hormones and other endocrine disrupting compounds. These included developing a new silylation solution to prevent the formation of undesired multiple derivatization products and conversion of trimethylsilyl derivatives of EE2 formed to their respective E1 derivatives reported in previous studies, and integrating an SPE method into GC-MS analysis, as well as the effects of solvent, temperature, and reaction time on the derivatization of EE2.

With the newly developed analytical method, we have determined the estrogenic hormones in seawater around Acushnet river estuary in Buzzards Bay. We have also carried out some preliminary studies on the photochemical degradation of estrogenic steroid hormones in Buzzards Bay seawater.

We presented our research results obtained in the project in professional conferences, published three papers in peer-reviewed international scientific journals, and are preparing two more manuscripts for publication soon.

For the educational component, I supervised three graduate students under this environmental estrogenic steroid research project. One of them, Jingping Wu, has just completed

his M.S. degree thesis defense. Another, Kai Zhang, is scheduled to have his research proposal defense on June 16, 2006 and Ph.D. thesis defense late this summer.

Project Findings:

1. The determination of estrogenic steroids, particularly in natural water systems, have been an analytic challenge for chemists due to the extremely low concentration of estrogenic steroids and interference from the sample matrices. Many immunoassay, gas chromatography (GC), gas chromatography-mass spectrometry (GC-MS), liquid chromatography (LC), and liquid chromatography-mass spectrometry (LC-MS) techniques have been developed for the determination of estrogenic steroid hormones in aquatic environments. GC-MS has been a preferred approach for simultaneous analysis of both synthetic and natural estrogenic steroids because of its superior separation and identification capabilities. In order to employ high-resolution GC for the analysis of estrogenic steroids, derivatization is required to increase analyte volatility and thermal stability and thus improve chromatographic separation. Many reagents are available for this purpose. Trimethylsilyl (TMS) derivatives are probably the most widely employed. The combination of *N*,*O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA) + trimethylchlorosilane (TMCS) is among the most popular silylating reagents used for the identification and quantification of estrogenic steroid hormones in water samples. However, several research groups reported on the formation of different derivatization products of EE2 with this silylating reagent [Shareef et al., 2004; Zuo and Zhang, 2005, Zhang and Zuo, 2005]. And thus suggested that derivatization with BSTFA + TMCS might not be suitable for the determination of EE2 by GC-MS under the previously reported conditions. In this project, we have developed a new silylation mixture (BSTFA :TMCS:pyridine = 49.5:05:50 (v/v/v)), overcome these pitfalls and generated a single product of di-TMS derivative of EE2 (Zuo and Zhang, 2005; Zhang and Zuo, 2005).

2. We have successfully applied our developed analytical procedure in the simultaneous

determination of both natural and synthetic estrogenic steroids (estrone and 17α-ethynylestrodiol) in Acushnet River estuarine seawater (Zuo et al., 2004). Our results have shown that the concentration of three common estrogenic hormones, 17α-ethinylestradiol, estrone and 17beta-estradiol, could be over 4.7, 1.2 and 0.83 ng/L, respectively, during the summer, which can certainly cause fish feminization in the Bay and may responsible for the significant decline in lobster population in Buzzards Bay (see photo below of an "intersex" lobster caught on the Massachusetts coast).

3. Our preliminary study has shown that EE2 can undergo a rapid photodegradation in estuarine seawater under natural sunlight irradiation, with a half-life of less than 1.5 days in spring sunny days. Previous studies have shown that natural estrogenic compound E2 can be oxidized to E1 by microorganisms in natural river water with half-lives of 0.2-9 days at 20^{o}C, and E1 is then further degraded at similar rates. Compared to E2, synthetic EE2 is much more resistant to biodegradation in natural water. Although EE2 is relatively resistant to microbial degradation, EE2, like other estrogenic steroids, contains a phenolic functional group, which is susceptible to photodegradation. To study the photochemical degradation of EE2 in seawater, EE2 was dissolved into seawater collected from Buzzards Bay and Acushnet River Estuary and irradiated under natural sunlight or simulated solar source in cylindrical quartz tubes (20 cm long x 1.4 cm i.d.). The results obtained indicate that the photochemical transformation represents a major fate of estrogenic steroids in natural surface water.

4. Three graduate students have been trained in this project to use the techniques developed to monitor and protect our aquatic environment from estrogenic pollutants.

Sources of E. coli during Wet-Weather Events

Basic Information

Title:	Sources of E. coli during Wet-Weather Events
Project Number:	2005MA52B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	MA 2&3
Research Category:	Water Quality
Focus Category:	Sediments, Non Point Pollution, Models
Descriptors:	
Principal Investigators:	Sarah Dorner

Publication

Sources of *E. coli* during Wet-Weather Events

Sarah M. Dorner, Jianyong Wu
Department of Public Health, University of Massachusetts Amherst
June 2006

1. Introduction: A Critical Regional Water Problem

Following the beginnings of modern water treatment more than a century ago, waterborne diseases such as cholera and typhoid fever were greatly reduced in the developed world. Then in 1993, an outbreak in Milwaukee, Wisconsin involving more than 400,000 cases of gastroenteritis caused by the protozoan parasite *Cryptosporidium parvum* was linked to the city's drinking water source (Mackenzie et al., 1994). Furthermore, in 2000, Walkerton, Ontario experienced a waterborne disease outbreak caused by the bacteria *E. coli* O157:H7 and *Campylobacter jejuni* resulting more than 2000 cases of gastroenteritis and seven deaths (O'Connor, 2002). Both of these outbreaks followed periods of heavy rainfall, as have others (Hrudey et al., 2002; Hunter, 2003).

The first recommendation of the report of Part 2 of the Walkerton Inquiry that examined the Walkerton waterborne disease outbreak was related to source water protection. It recommended that all drinking water sources be protected through the development of watershed-based source water protection plans (O'Connor, 2002). Therefore, it is now widely accepted that source water protection is an element of ensuring the safety of our drinking water supplies. However, what is less well understood is how to determine if a water source is adequately protected, particularly as greater urbanization and agricultural intensification are placing increasing pressures on our water resources.

Many waterborne pathogens may also be transmitted through food or direct contact with infected individuals or animals, but once present in a given population, pathogens can enter watercourses via a variety of sources. Pathogens sources in a watershed can include wildlife, agriculture, treated wastewater discharges, combined sewer overflows, and storm water runoff. Other specific examples of sources of pathogens are manure spread on land, the unintentional leakage from sewers and septic systems, or manure storage facilities.

In watersheds with a high population density and significant agricultural production, determining the survival times and pathways of pathogens in the environment once released helps to establish the frequency of high levels of pathogens arriving at a water treatment plant that could overwhelm the system. It is essential that treatment plants be capable of handling peak concentrations of pathogens. Information regarding baseline levels and peak concentrations of major pathogens of concern should be available to ensure robust treatment plant design. However, this information is often unavailable, in part because of the cost involved in collecting the data and uncertainty in the methods used for enumeration of pathogens such as *Cryptosporidium* spp. Furthermore, few modeling studies have been performed that could offer additional insight into probable pathogen concentrations, partially a result of a lack of data. Information regarding the sources of pathogens is needed for evaluating the impact of management practices aimed at reducing pathogen loads. Deeper knowledge of the relative importance of the sources will permit strategic targeting of remedial measures for pathogen reduction.

Stream sediments are potentially important reservoirs of pathogenic microorganisms. During hydrologic events, pathogens may be resuspended from the sediments to the overlying water column. The relative importance of land-based versus sediment based sources of pathogens and indicators is important for the development of source water protection plans, as well as modeling the fate and transport of pathogens at a watershed-scale.

Through the use of both monitoring and modeling, an overall goal of this study is to assess the temporal and spatial variability of *E. coli* in stream sediments and in the water column. The information gained from this study will assist in the identification of primary contributing potential sources of pathogens in such a watershed and will have the potential to positively influence the implementation of management practices with regard to their efficiency and effectiveness.

The specific objectives of this investigation were to:

- determine *E. coli* densities in water and sediment samples, with particular emphasis on storm water samples,
- estimate the absolute and relative numbers of *E. coli* from land based and sediment sources,
- identify the environmental conditions such as temperature, solar radiation, hydrologic conditions (i.e. antecedent moisture content, streamflow, precipitation) that contribute to peak occurrences of *E. coli*,
- increase our fundamental understanding of the mechanistic behavior of microbial fate and transport, and
- develop a set of recommendations for assessing source waters for pathogenic contamination.

2. Materials and Methods

Study site

The Blackstone River originates in the Worcester hills in central Massachusetts, and flows southeasterly into Rhode Island, discharging eventually into Narragansett Bay. Like many major waterways in the New England region, the water and sediment quality of the Blackstone River watershed was historically impaired by intense industrial development and urbanization (Figure 1), resulting in the discharge of untreated industrial and domestic wastes. The presence of numerous dams along the river, with at one point as many as one dam for every one mile of river, significantly impacted the fate and transport of these historical contaminants. The river continues to be plagued today by contaminated sediments trapped upstream of these impoundments.

Significant improvements in the overall water quality of the Blackstone River have been made in the past 30 years as a result of the Clean Water Act and the other pollution reduction initiatives. Despite this, the entire mainstem Blackstone River in the Massachusetts portion of the basin is impaired (defined as partial support and non-support) with respect to aquatic life and primary/secondary use attainment (MADEP 2002 303(d) List). Additionally, segments of the Blackstone River in Rhode Island fail to meet that state's water quality standards. According to the 2002 303(d) List of Impaired Waters prepared by the Rhode Island Department of Environmental Management (RIDEM), causes of impairment include biodiversity, excess algal growth, lead and copper, low dissolved oxygen concentrations, and pathogens.

The monitoring consisted of wet weather event sampling for *E. coli*. Events to be sampled were selected based on meteorological forecasts. A minimum of one water sample (with duplicate) and one sediment sample (with duplicate) were collected per sample location. The monitoring scheme was designed to complement past- and on-going data collection efforts by other organizations working in the watershed.

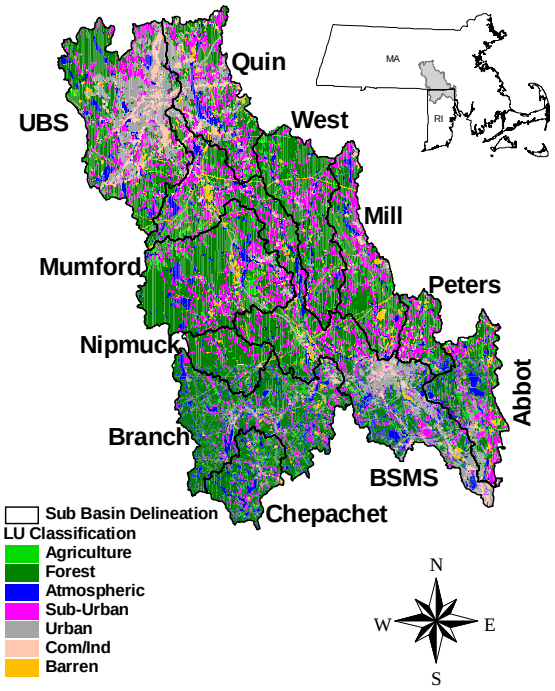

Figure 1. Land Use in the Blackstone River Watershed.

Site Descriptions:

BS1: BS1 is at the USGS Millbury Gauge. It is located downstream of the effluent discharge of the Upper Blackstone Water Pollution Abatement District.
BS4: BS4 is located on the Blackstone River upstream of the Upper Blackstone Water Pollution Abatement District.
MR2: MR2 is located on the Middle River, a tributary of the Blackstone River.

Method for the Enumeration of *E. coli*

Sample collection: During wet weather, surface water and sediment samples were collected 6 times in 3 sites from the Blackstone River. At times, sediment samples were not possible to collect due to excessive flooding. Water samples near the sediments were also collected. Water samples were taken in 500ml bottles and sediment samples with some water were taken by a long glass pipet in small bottles. All the bottles were sterilized. The samples were kept in an ice cooler and sent back immediately for analysis within 4 hours.

Enumeration of *E. coli*: *E. coli* was monitored by Colilert method (IDEXX Company, USA). Water samples were diluted with PBS buffer by 10 or 100 times. Then, 100 mL of diluted liquid was placed into vessels and reagents were added and mixed. The mixtures were poured into Quanti-Tray®/2000**,** sealed in a Quanti-Tray® Sealer and placed in incubator for 24 hours at 35 ± 0.2 ºC. The yellow wells in the trays indicated the presence of total coliforms, and the yellow wells with fluorescence indicated the presence of *E. coli*. Total coliforms and *E. coli* were enumerated using an IDEXX Quanti-Tray®/2000 MPN table. For sediment samples, sediments were resuspended within the existing water matrix and hand shaken for several minutes. Then 10ml of liquid was placed into vessels and diluted either 10 or 100 times. The ensuing steps were the same as for water sample analysis described above.

Statistical analysis
Statistical analysis was carried out using SPSS 12.0 software. The Pearson correlation coefficients were calculated for *E. coli* and total coliforms in water and sediments

3. Results and Discussion

E. coli in water samples
At site BS1, *E. coli* concentrations gradually increased from May 9 to May 14, and then decreased to baseline levels on May 17. At site BS4, *E. coli* concentrations fluctuated with the peak concentration occurring on May 12. A similar trend was observed at site MR2 (Table 1), possibly reflecting a different response following heavy precipitation.

Table 1. *E. coli* densities in water samples

Date	BS1 (MPN/100mL)			BS4 (MPN/100mL)			MR2 (MPN/100mL)		
	Min	Max	Geometric mean	Min	Max	Geometric Mean	Min	max	Geometric mean
May 9	185	310	243	1210	1455	1305	520	630	554
May 10	200	410	288	200	520	340	100	630	204
May 12	200	520	322	2000	4100	2576	1870	2000	1946
May 13	520	987	692	730	1076	869	602	1100	812
May 14	960	1710	1401	934	1460	1243	1200	1989	1472
May 17	100	228	176	450	980	655	175	410	252

Table2. *E. coli* densities in sediment samples (per gram dry weight)

Date	BS1 (MPN/g)			BS4 (MPN/g)			MR2 (MPN/g)		
	Min	max	Geometric mean	Min	Max	Geometric Mean	Min	max	Geometric mean
May 9	NA	NA	NA	23	82	47	10	29	19
May 10	2	11	5	6	17	10	7	14	10
May 12	8	8	8	46	57	52	39	227	83
May 13	35	84	52	11	123	40	71	169	106
May 14	NA	NA	NA*	NA	NA	NA*	202	476	277
May 17	5	58	14	13	49	25	14	24	18

*NA – Not available due to excessive flooding

E. coli in sediments

At site BS1, *E. coli* concentrations were highest on May 13 and decreased to baseline concentrations on May 17. At site BS4, the concentration of *E. coli* varied slightly over the course of the event. At MR2, *E. coli* concentration increased sharply from May 10 to May 14, and deceased to normal on May 17(Table 2).

Statistical analysis

Pearson correlation analysis illustrated that there existed significant correlations between *E. coli* and total coliforms in water (r= 0.397, p=0.0020) and sediments (r=0.728). In addition, *E. coli* concentrations in water were significantly correlated with sediment concentrations (r=0.318, p=0.018). These relationships also demonstrated in Figures 2 to 4.

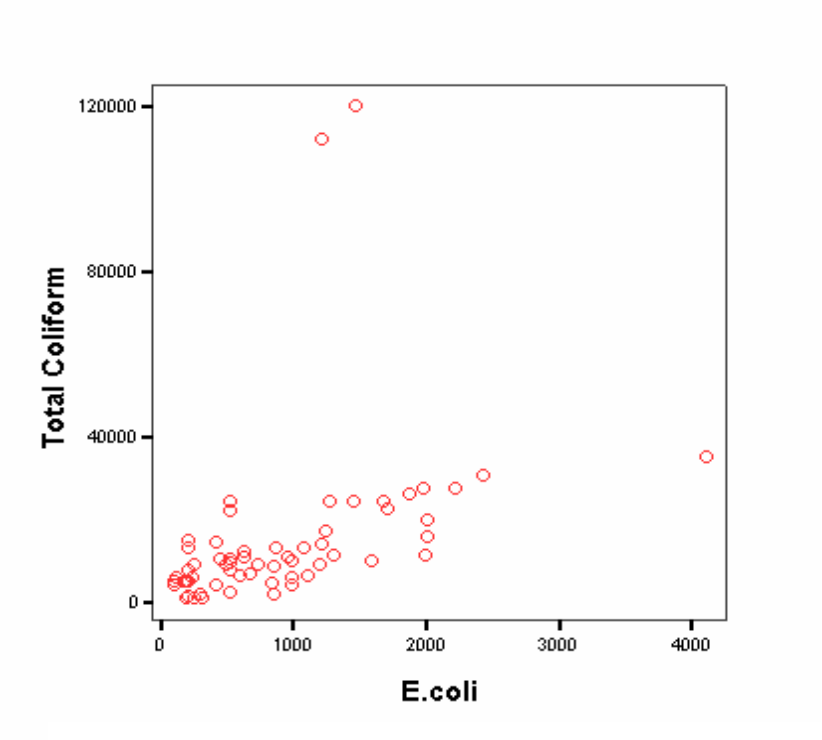

Figure 2. Relationship of *E. coli* and total coliforms in water (MPN/100 mL)

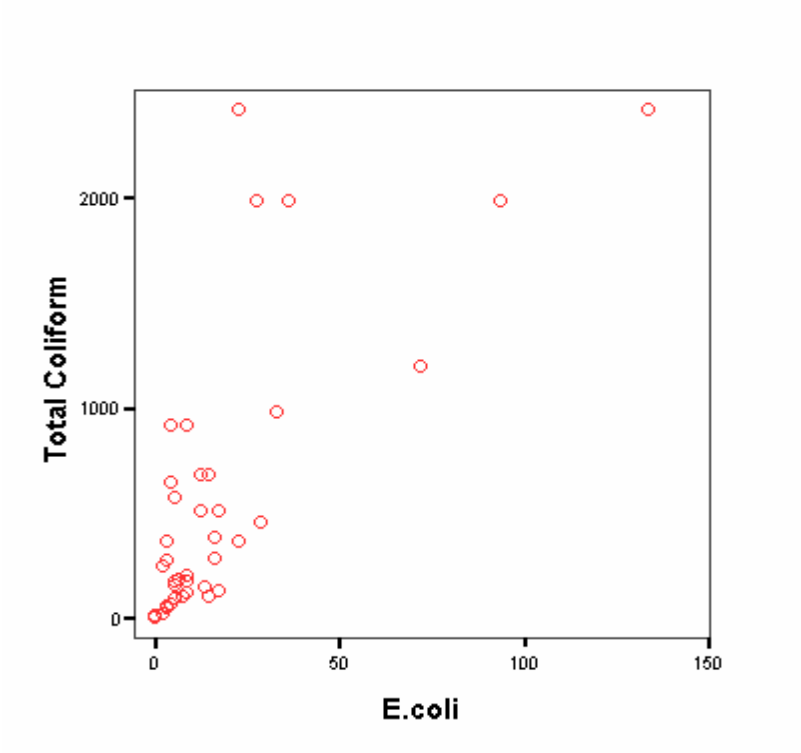

Figure 3. Relationship of *E. coli* and total coliforms in sediments (MPN/ g dry weight)

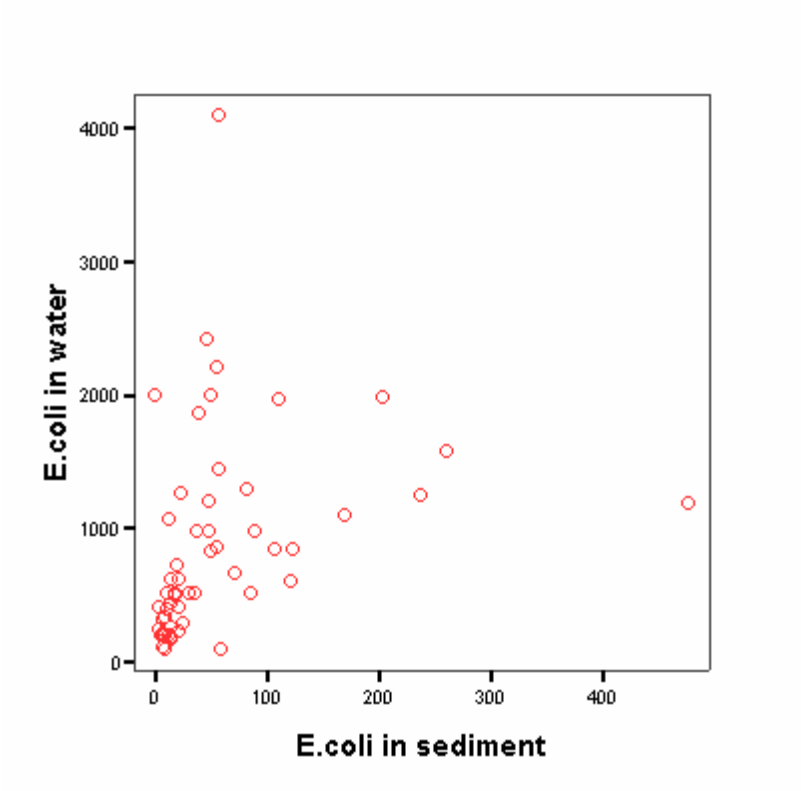

Figure 4. Relationship of *E. coli* in water (MPN/100 mL) and sediments (MPN/g dry weight)

The primary study demonstrated the spatial and temporal patterns of fecal indicator concentrations in the surface water and sediments of the Blackstone River, and also gave an indication of the source and transport pathways of the pathogens. According to the results, wet weather clearly impacts *E. coli* concentrations. Following the variation of precipitation, the number of the *E. coli* was changed accordingly. However, for the Blackstone River it is not clear that the increase of *E. coli* in the surface water is originating from the sediments as *E. coli* in the sediments followed the same general trends as for the surface water. Isolated and confirmed *E. coli* will be further analyzed by ribotyping methods.

The proposed research will provide a greater mechanistic understanding of the fate and transport of *E. coli*, a primary microbial indicator of water quality. The expected results of this investigation include a better understanding of environmental factors with respect to the numbers of pathogenic microorganisms arriving at a water treatment plant, as well as more detailed information on sources of pathogens in a complex watershed. This study will provide water managers and regulators with reliable information to help them develop strategies for source water protection for drinking water and for other important uses of the watershed such as recreation.

4. Training

One MS student was supported by the project, and one additional student was trained to conduct field and lab measurements. Both students are in the Department of Public Health at UMass Amherst.

5. Dissemination of Results

One abstract has been accepted for the upcoming AWWA Source Water Protection Conference. A manuscript has been written and will be submitted in summer 2006.

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Information Transfer Program

Third Annual Water Resources Research Conference

Basic Information

Title:	Third Annual Water Resources Research Conference
Project Number:	2005MA71B
Start Date:	3/1/2005
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	1st District of MA
Research Category:	Not Applicable
Focus Category:	Water Quality, Water Quantity, Surface Water
Descriptors:	
Principal Investigators:	Sarah Dorner, Marie-Francoise Walk

Publication

The Water Resources Research Center held its third annual Water Resources Research Conference*, Research to Practice: Science for Sustainable Water Resources*, October 21, 2005 at UMass in Amherst. New this year was the cooperation of the Cooperative State Research, Education, and Extension Service New England Regional Program who helped with conference planning and fundraising. Five co-sponsors helped underwrite the cost of the conference. Over two hundred people attended the conference (188 pre-registered, and close to 50 walk-ins, including many local university and college students). The 188 pre-registered participants can be categorized as follows:

Category	**Number of participants**
Academic	106
Agency	30
Commercial/Consultants	20
Government	1
Individuals (unaffiliated)	2
Municipal	2
Non-profit	27

Thirty-five posters were presented and there were 36 paper presentations in three concurrent sessions. The presentations were grouped into four tracks subdivided into three sessions each:

Biological Response and Ecological Impacts
- Climate Change
- Integrative Modeling for Sustainable Waters
- Habitat Alteration

Critical Contaminants
- Endocrine Disruptors
- Perchlorate
- Metals

Water Resources Monitoring, Modeling, and Assessment
- Groundwater
- Pathogens
- Cyber Infrastructure and Sensor Networks

Protecting and Restoring Water Resources
- Protecting Water Quality
- Creating a Watershed Community
- Stormwater Management

The Keynote Address was given by Sandra Postel, Director of the Global Water Policy Project, and Brian Richter, Director of The Nature Conservancy's Sustainable Waters Program, on the topic of the book they co-wrote, *Rivers for Life: Managing Water for People and Nature*. Postel and Richter were given the 2005 MA Water Resources Research Center John W. Olver Leadership Award. This award is presented to individuals who have made exceptional contributions and shown great leadership in environmental research and in protecting our natural resources.

This was the first year that we officially requested participants' evaluation of the conference. Overwhelmingly, participants liked the diversity of topics offered, the caliber of speakers, the interdisciplinary perspectives. The keynote speakers (Sandra were extremely well received. The poster session was also rated as very informative and useful, though too limited in time. Example of the evaluations we received:

"For the second year in a row, I was fortunate to be able to attend the Water Resources Conference. I found it very well-organized and efficiently run. Like most conferences with concurrent sessions, there were a couple of times when I wished I could be in two or more places at once. That speaks to the quality of the conference. Keep up the great work."

The complete conference program can be seen at http://www.umass.edu/tei/wrrc/WRRC2004/2005%20Conference.htm.

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.	2	1	0	0	3
Post-Doc.	0	0	0	0	0
Total	6	1	0	0	7

Notable Awards and Achievements

Publications from Prior Projects

1. 2003MA8B ("Copper Removal by Biofilms") - Articles in Refereed Scientific Journals - Zhang, X., Brussee, K., and J. Rooney-Varga, 2006, Impacts of Chemical Stress Induced by Copper: Examination of a Biofilm System, Water Science and Technology (Under review).
2. 2003MA8B ("Copper Removal by Biofilms") - Water Resources Research Institute Reports - Zhang, X., 2006, Copper Removal by Biofilms, MA Water Resources Research Center Publication No. 179, 10 pp. http://www.umass.edu/tei/wrrc/WRRC2004/WRRCrecentpubs.html
3. 2003MA9B ("Potential Movement of Pesticides Related to Dissolved Organic Matter from Organic Fertilizer Application on Turf") - Articles in Refereed Scientific Journals - Li, K., B. Xing, and W.A. Torello, 2005, Effect of organic fertilizers derived dissolved organic matter on pesticide sorption and leaching, Environ. Pollut. (134)187-194.
4. 2003MA9B ("Potential Movement of Pesticides Related to Dissolved Organic Matter from Organic Fertilizer Application on Turf") - Articles in Refereed Scientific Journals - Heymann, K., H. Mashayekhi, and B. Xing, 2005, Spectroscopic analysis of sequentially extracted humic acid from compost, Spectroscopy Letters, 39(3): 293-302.
5. 2003MA9B ("Potential Movement of Pesticides Related to Dissolved Organic Matter from Organic Fertilizer Application on Turf") - Dissertations - Li, K., 2004, Evaluation of organic turfgrass management and its environmental impact by dissolved organic matter, Ph.D. Dissertation, Department of Plant, Soil and Insect Sciences, University of Massachusetts at Amherst, Amherst, MA, 101 pp.
6. 2003MA9B ("Potential Movement of Pesticides Related to Dissolved Organic Matter from Organic Fertilizer Application on Turf") - Water Resources Research Institute Reports - Xing, Baoshan, 2006, Potential Movement of Pesticides Related with Dissolved Organic Matter from Organic Fertilizer Application on Turf, MA Water Resources Research Center Publication No. 180, University of Massachusetts, Amherst, MA, 20pp. http://www.umass.edu/tei/wrrc/WRRC2004/WRRCrecentpubs.html