



MA Water Resources Research Center

Annual Report FY 2007



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Front cover photograph by Marie-Françoise Walk – Tannery Falls, Savoy, MA



Table of Contents

Table of Contents	3
Introduction	4
Research Program.....	5
1. A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management (USGS 2003MA19G).....	5
2. Using Hydromorphological Signatures to Determine Flow Related Habitat Thresholds for Instream Communities (USGS 2006MA60B).....	8
3. Environmental Behaviors of Engineered Nanoparticles in Water	25
4. Development of a Standardized Protocol for Fish Bioassays.....	26
Detecting Estrogenic Exposure (USGS 2007MA74B)	26
2. Orlando EF et al,. 2004. Endocrine-disrupting effects of cattle feedlot effluent on an aquatic sentinel species, the fathead minnow. Environ Health Perspect. 112(3): 353–358.	28
5. Acid Rain Monitoring Project (MADEP).....	30
Information Transfer Program	30
1. Water Resources Conference 2008	30
2. Innovative Stormwater Technology Transfer and Evaluation Project (MADEP) ..	31
3. Stream Continuity Project	32
4. Other Information Transfer/Outreach	32
Other Activities	33
Financial Overview	35



Introduction

This report covers the period March 1, 2007 to June 30, 2008¹, the 42nd year of the Massachusetts Water Resources Research Center (WRRC). The Center is under the direction of Dr. Paula Rees, who holds a joint appointment as Director of the WRRC and as Director of Education and Outreach of the Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere at the University of Massachusetts Amherst.

Dr. Stephen Mabey of the UMass Amherst Department of Geosciences completed the three-year 104G USGS grant to look at *A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management*.

Piotr Parasiewicz of the University of Massachusetts Amherst finished the two year project *Using Hydromorphological Signatures to Determine Flow Related Habitat Thresholds for Instream Communities*.

The center awarded the first year of a two-year grant to Dr. Baoshan Xing of the UMass Plant, Soil, and Insect Science Dept. to study *Environmental Behaviors of Engineered Nanoparticles in Water*.

A UMass Amherst graduate student project on *Development of a Standardized Protocol for Fish Bioassays Detecting Estrogenic Exposure*, by Lauren Moffat of the Animal Biotechnology and Biomedical Sciences Dept. and Dr. Kathleen Arcaro of Veterinary and Animal Sciences was also supported this year through the WRRC grant program.

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. The Center is also working on a stormwater clearinghouse project that enables users to search the web for stormwater Best Management Practices and to find innovative technologies available to treat stormwater.

WRRC was involved in three projects incorporating modern information technology into environmental research, teaching at the middle school and University levels, and public outreach in the Connecticut River watershed. All three use location-aware hardware and software technologies and handheld computers to enhance understanding of complex, place-based environmental issues.

The fifth annual water resources research conference, *Integrating Water Resources Management*, was held at UMass on April 8, 2008.

¹ The USGS reporting year covers March 1 to February 28, while the University of Massachusetts and the Commonwealth of Massachusetts fiscal years run from July 1 to June 30. Projects funded by the State are reported for the period July 1 2007 - June 30, 2008.



Research Program

Four research projects were conducted this fiscal year: two research projects were funded through the USGS 104B program continued for a second year and are slated to complete in December and February of 2008; another 104B-funded two-year project was initiated this year, as well as a new one year student project. Finally, one project funded through the 104G Program neared completion of its fourth year of research; Progress reports for all four projects follow:

1. A Regional Approach to Conceptualizing Fractured-Rock Aquifer Systems for Groundwater Management (USGS 2003MA19G)

Principal Investigators: Stephen B. Mabee, State Geologist, UMass Amherst and Michele Cooke, Professor, UMass Amherst Geosciences

Start Date: 9/30/2004

End Date: 12/27/2008

(extension requested through May 2008)

Reporting period: March 1 2007 – February 29 2008

Research Category: Groundwater Flow

Focus Category: Water Supply, Groundwater, Water Quantity

Descriptors: Fracture Characterization, Domain Analysis, Well Yield, Fractured Rock Aquifers, Groundwater Availability, Groundwater Mapping, Borehole Geophysics

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 requires 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 televiwer 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 (e.g., overburden type and thickness); and
5. Conceptual Model - preparation of a qualitative conceptual model of ground water flow behavior in each litho group category.

Work completed during the period March 1, 2006 to February 28, 2007:

1. Tasks 1 (Fracture Characterization and Domain Analysis), 2 (Compilation and Analysis of Existing Well Data) and 4 (Compilation of Regional Litho-Group Map) are complete.
2. Task 5 (Conceptual Model) is underway. Discrete fracture network models are being run for individual outcrops to test the concept of hydrostructural domains. Model results will be compared with well field pumping test data and the borehole geophysical data. Existing pumping test data has been collected and is being analyzed.
3. Task 3 (Borehole Geophysical Surveys) was underway during the summer of 2007.
4. We are 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.

Although the project technically ended on September 29, 2007, it is under a no-cost extension as Alex Manda will be continuing the model validations through the 2007/2008 academic year in order to complete his Ph.D.

Students Supported:

- 1 PhD student in Geosciences Department at University of Massachusetts Amherst.

Publications and Presentations:

Manda, A.K; S.B Mabee, D.U. Wise, In prep. Influence of rock fabric on fracture attribute distribution and implications for groundwater flow in the Nashoba Terrane, Eastern Massachusetts, to be submitted to Journal of Structural Geology.



Manda, A.K, S.B. Mabee and D.F. Boutt, 2006. Characterizing fractured crystalline bedrock aquifers using hydrostructural domains in the Nashoba terrane, eastern Massachusetts. Geological Society of America Annual Meeting, Philadelphia, Abstracts with Programs, v.38, no.7, p.25.

Diggins, J.P., D.F. Boutt, A.K. Manda and S.B. Mabee, 2006. Estimating bulk permeability of fractured rock aquifers using detailed outcrop data and discrete fracture network modeling. Geological Society of America Annual Meeting, Philadelphia, Abstracts with Programs, v.38, no.7, p.223.

Boutt, D.F., A.K. Manda, S.B. Mabee, J.P. Diggins, 2006. Characterizing fractured crystalline bedrock aquifers using discrete fracture networks in the Nashoba Terrane, Eastern Massachusetts, Eos Transactions, American Geophysical Union, v. 87, no. 52, Fall Meeting Supplement, Abstract H13D-1429.

Manda, A.K., S.B. Mabee and S.A. Hubb, 2005. Field mapping and fracture characterization techniques predict groundwater preferential flow paths in fractured bedrock aquifers, Nashoba terrane, MA. EOS Transactions, American Geophysical Union, v.86, no. 52, Fall Meeting Supplement, Abstract H23E-1477.

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. Using Hydromorphological Signatures to Determine Flow Related Habitat Thresholds for Instream Communities (USGS 2006MA60B)

Principal Investigators: Scott Jackson, Department of Natural Resources Conservation, University of Massachusetts Amherst; Piotr Parasiewicz, Northeast Instream Habitat Program, Amherst, MA; and Christina M. Cianfrani, School of Natural Science, Hampshire College;

End Date: February 29, 2008

Reporting period: March 1 2007 – February 29 2008

Focus Categories: Hydrology, Ecology, Management and Planning

Introduction

Field measurements from the existing database of streams in the northeastern United States were used to evaluate the feasibility of using hydromorphological (HMU) signatures in determining fish communities as part of an overall methodology for quantifying instream flow requirements and habitat thresholds. The results of this research may lay the foundation for using HMU signatures to identify thresholds of change in aquatic communities as a result of changes in hydrologic regime due to water withdrawals/alterations. These thresholds could then begin to provide the scientific basis for determining acceptable limits of hydrologic change within river systems to protect ecological integrity.

This project builds upon a newly developed French method (Le Coarer, 2005) of using hydraulic (velocity and depth) distribution score-cards, called "Hydrosignatures," as a habitat metric. We apply this concept to represent the distribution of HMUs in the stream for different flow conditions (e.g. high, medium, low). We then attempt to use these HMUs to create templates that can be used with fish habitat models in an attempt to predict the probable composition of fish communities associated with these patterns. This final report presents the results from both the first and second years (Phase I and II) of the study

PHASE I (Year 1)

The purpose of Phase I of this project was to use existing data to show proof of concept of a method to: 1) identify and map HMU signatures for river sections under different flow conditions; and 2) relate the HMU signatures to physical habitat. To accomplish this, data including habitat and HMU mapping, flow-duration curves, and fish habitat models (generated using MesoHABSIM) were used to compute the relative area available for habitat for individual species under varying flow conditions (high, medium, and low summer flows) (Figure 1). This was completed for both existing summer flow durations as well as modeled pristine flow conditions.

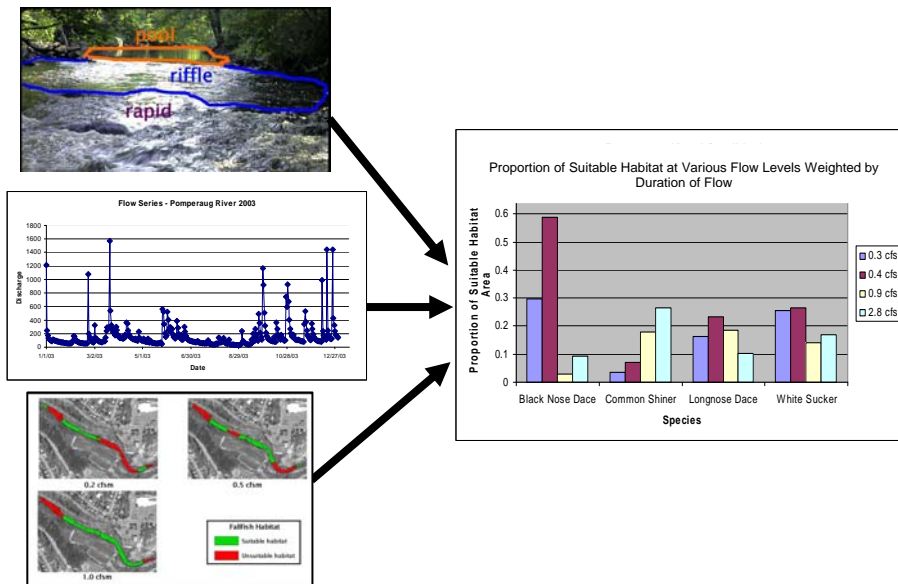


Figure 1. Basic methodology to create habitat probability models under various flow conditions.

Hydraulic and Fish Data

As part of previous projects, HMUs were mapped in the field for ten rivers in Connecticut, Massachusetts, New Hampshire, and New York. Each HMU was mapped using a personal digital assistant (PDA) and ArcPad software (ESRI, Redlands, CA). Aerial photographs uploaded to the PDA were used to help identify river locations. Eleven HMU categories were used when mapping with definitions taken from Parasiewicz (2001): 1) backwater; 2) pool; 3) plungepool; 4) glide; 5) run; 6)

fastrun; 7) rapids; 8) sidearm; 9) cascade; 10) ruffle; and 11) riffle. Within each HMU, random velocity and depth measurements were taken.

Fish were collected using a backpack electro-shocker and a grid technique described by Bain et al. (1985). Sampling occurred in representative HMUs at each site on each river to ensure each type of habitat was appropriately represented. Fish were measured and identified to species.

Considerable effort was spent in year 1 of the project mining data from existing projects. Specific river sections were chosen according to project criteria. Data was then formatted for compatibility.

Habitat Suitability

Sites on the Quinebaug and Pomperaug Rivers were used to test the ability of the technique to detect differences in suitable habitat availability based on changes in flow regimes. Using four key species (as defined by the target fish community identified for the Quinebaug River), changes in habitat availability were modeled for four summer flow levels under two flow regimes, measured and 'pristine' (Figure 2). The regimes differed in percent duration of low, medium, and high flows.

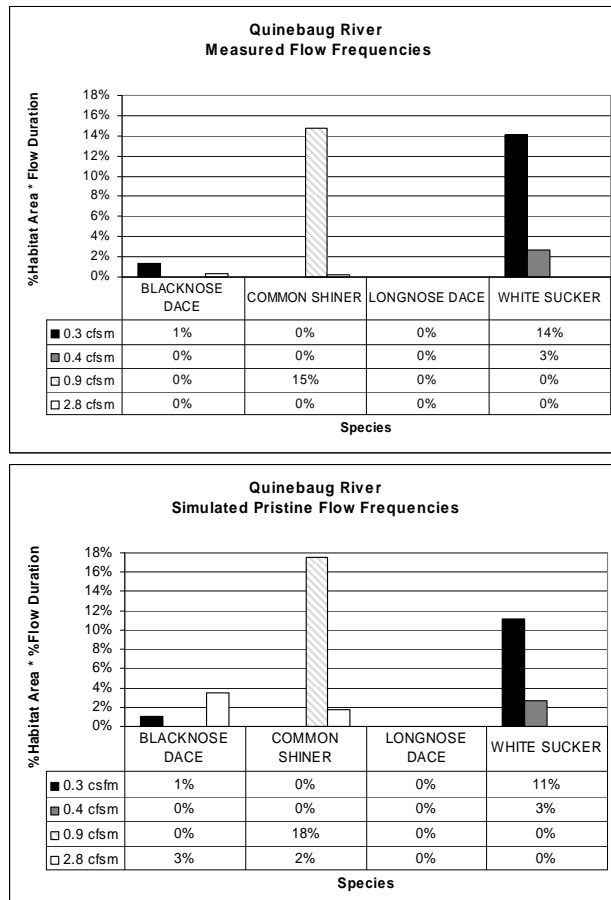


Figure 2. Available habitat (as percentage of total wetted width) for the Quinebaug River under two flow regimes weighted for duration during the summer.



The amount of available habitat was not sensitive to significant changes in flow regimes using this technique. Further analysis is needed to determine which component(s) may need adjustment in order to detect the differences. For example, research as part of another project has shown the choice of fish habitat model can have a significant impact on overall results. This study compared the predictive capability of models developed using: 1) three rivers individually (each with differing levels of impairment); 2) a regional model using significant parameters from all three rivers; and 3) a global model using all field collected data for all rivers. Such considerations will be explored as the model is refined.

HMU Classification

We explored the possibility of reducing the number of HMUs through cluster analysis. We analyzed trends among the high, medium, and low flow data of the HMUs used in the field mapping protocol. We aim to develop a standardized characterization, or template, of depth and velocity for each HMU to use in fish habitat models. If templates can be developed based on HMUs, field work effort could be reduced significantly (i.e. one would only have to map the HMU and take a minimal number of depth and velocity measurements). More than one potential "template" may result if distributions vary for different flow levels.

Preliminary k-means hierarchical cluster analysis (McGarigal, et al, 2000) was used to reduce the number of HMUs. The analysis using depth and velocity measurements showed a reduction was possible in the number of HMUs from 11 to 8. This analysis resulted in the following HMUs: 1) backwater; 2) pool; 3) glide/run; 4) plungepool; 5) sidearm; 6) cascade; 7) ruffle/riffle; and 8) fastrun/rapids.

For the second part of this analysis, histograms for the depth and velocity measurements for each HMU for each flow (high, medium, low) were created. Bins were predetermined as per NEIHP protocol with bin size for depth equal to 25 cm and for velocity equal to 15 cm/s. The histograms were standardized and plotted to inspect for visual trends (Figure 3). Visual inspection was followed with Kolmogorov-Smirnov tests (Davis, 2002) in a pairwise fashion for all combinations of the three flow data sets within each HMU (i.e. low vs medium, medium vs high and high vs low). This test was used to determine which data sets could be combined. This was repeated for both depth and velocity data. Preliminary results show that few data sets can be combined and that templates for each HMU for each flow will most likely be necessary.

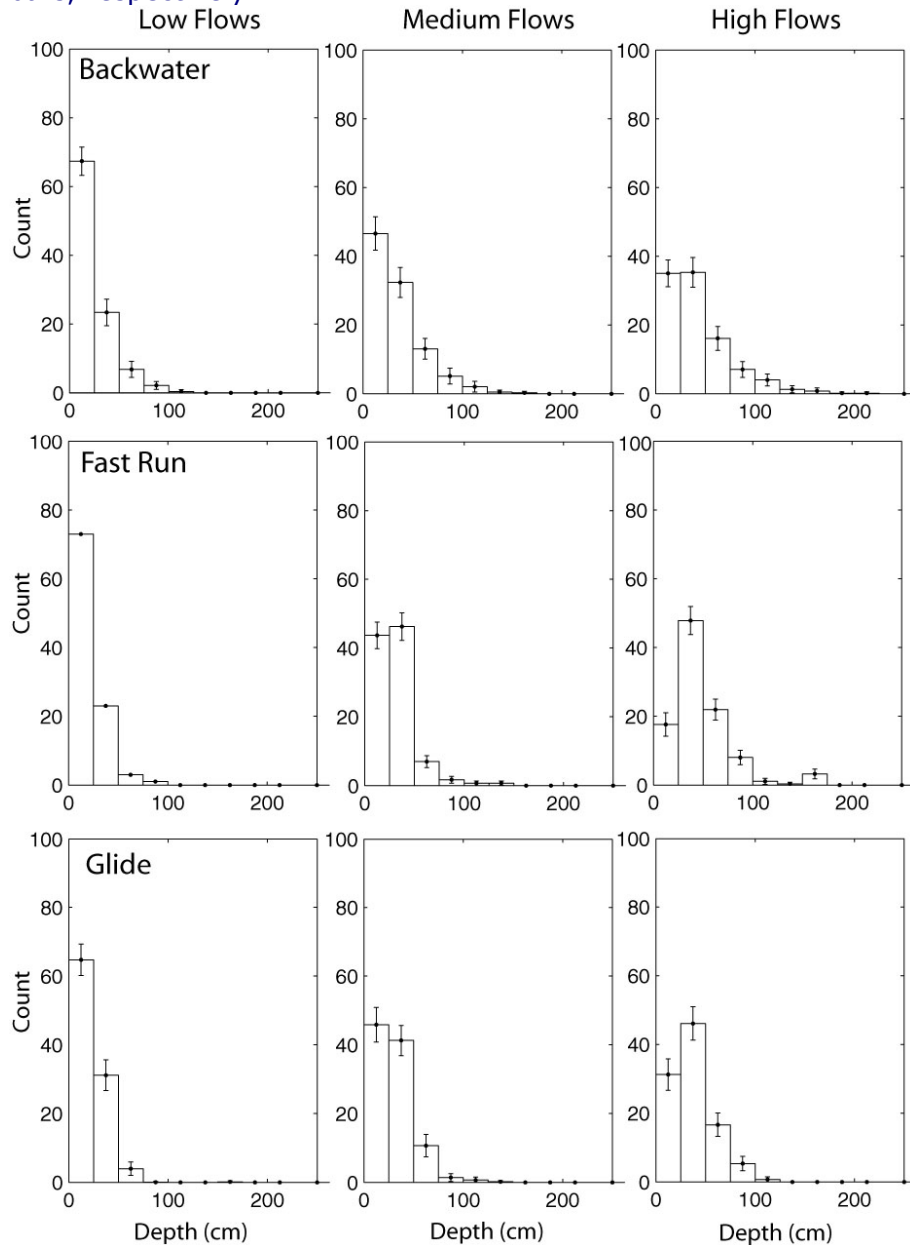
PHASE II (Year 2)

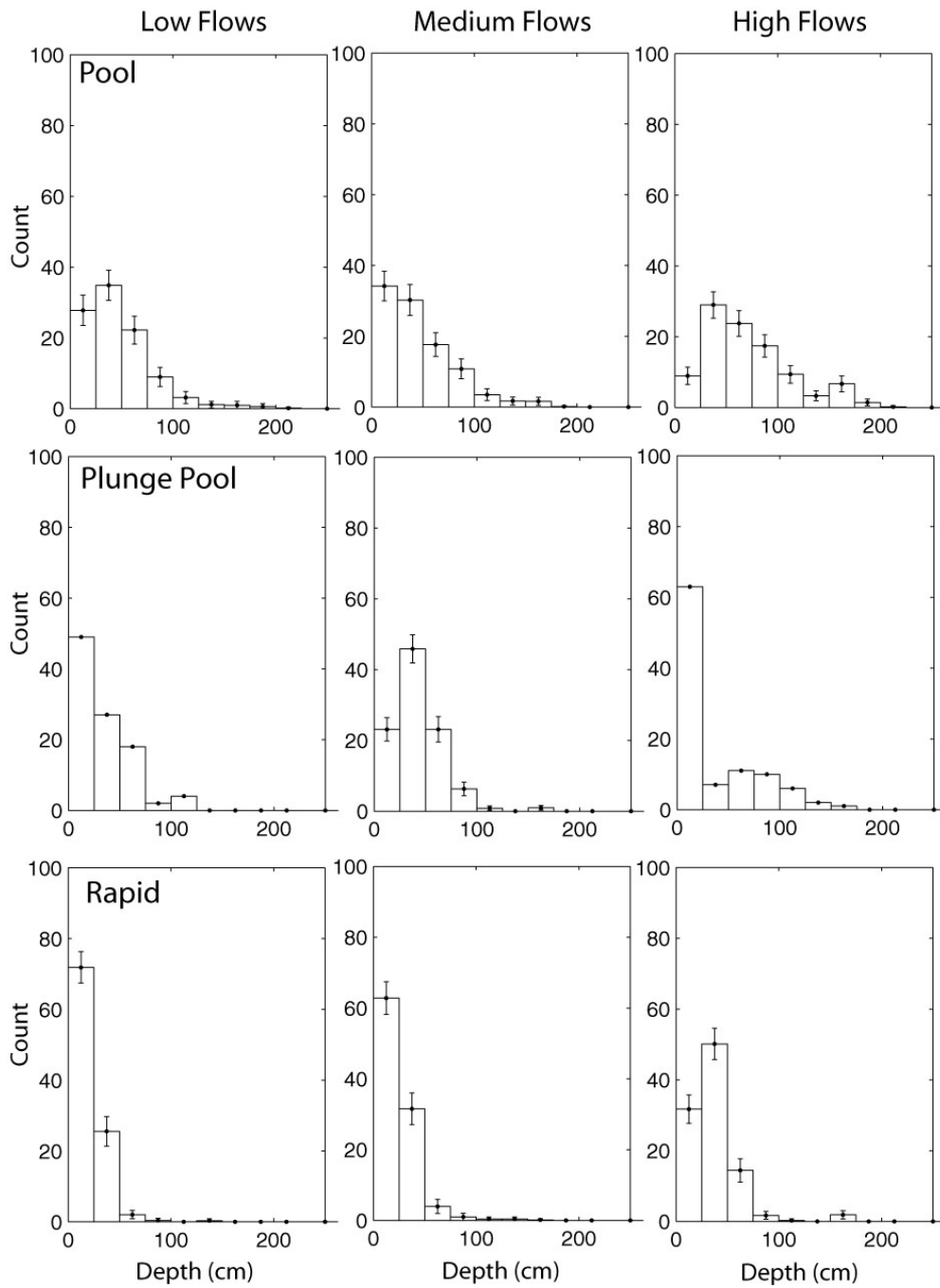
In the second year of the project, we continued evaluating the modeling approach outlined in Phase I. We completed extensive statistical analyses that: 1) clustered and reduced the number of HMU categories; 2) identified distribution curves for the reduced number of HMUs across 3 different flows; 3) quantified the similarities and differences in distributions across flows for a given HMU; 4) found distribution fits for a given HMU within each flow; and 5) generated signature plots for paired data and quantified the statistics differences. The results of these analyses are found below.

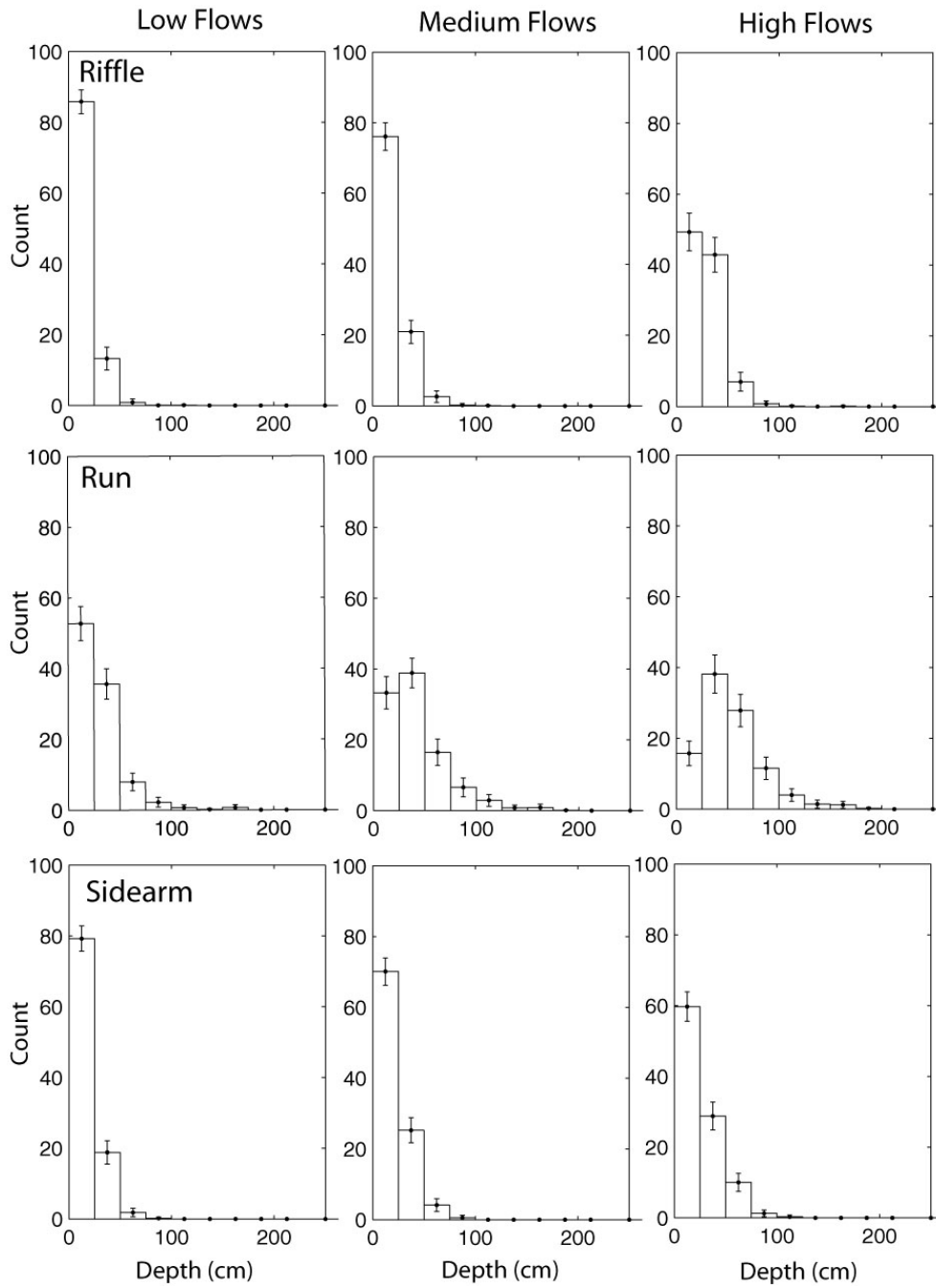
Steps 1) and 2): Generate distribution curves, aggregating cascade and rapids (Rapids) and ruffle and riffles (Riffles)

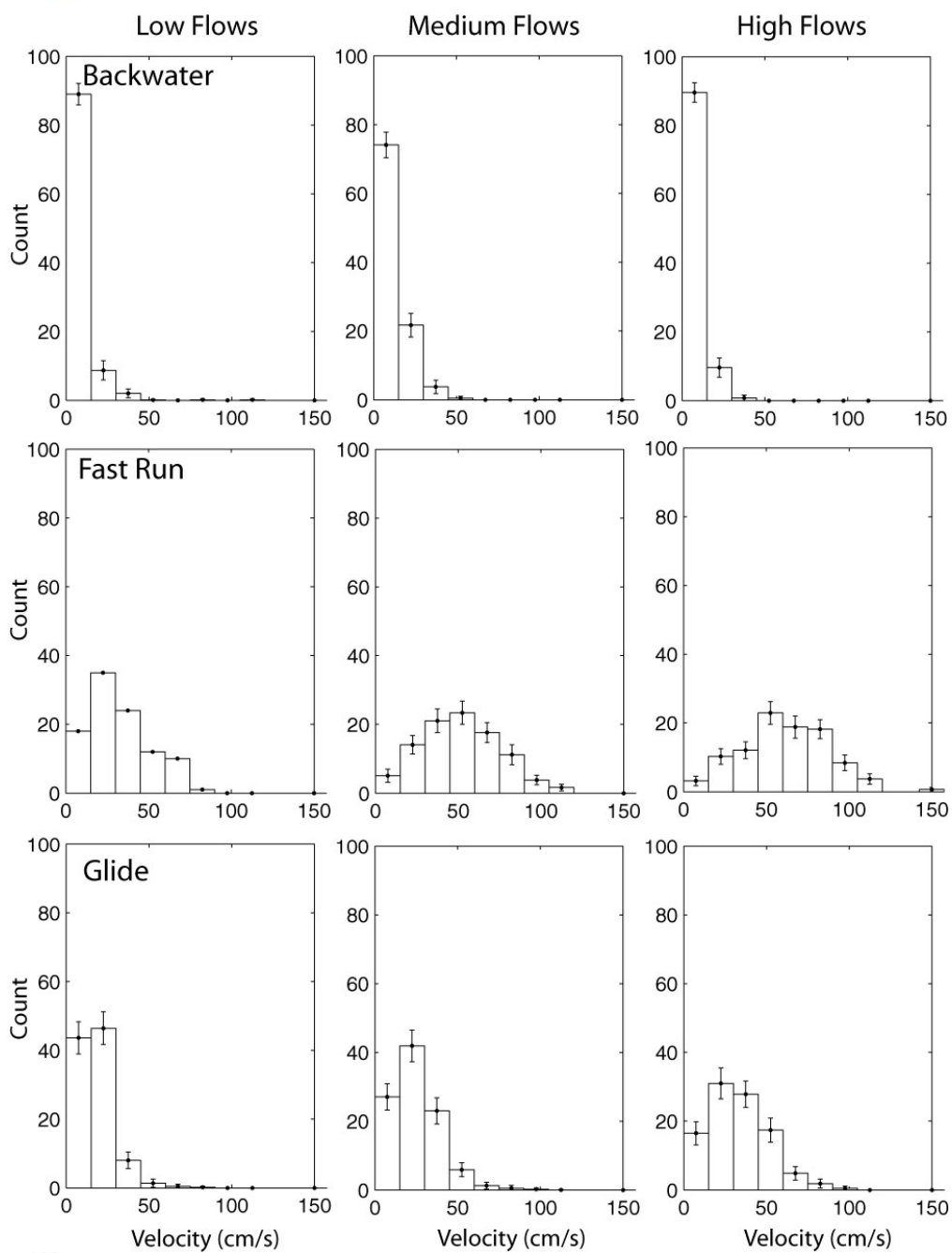
The following six figures (3 for depth, 3 for velocity) represent depth and velocity distributions for the three specified flow conditions (low, medium, high flows) across 9 defined HMUs. A pre-specified bin spacing was used for either depth (every 25 cm)

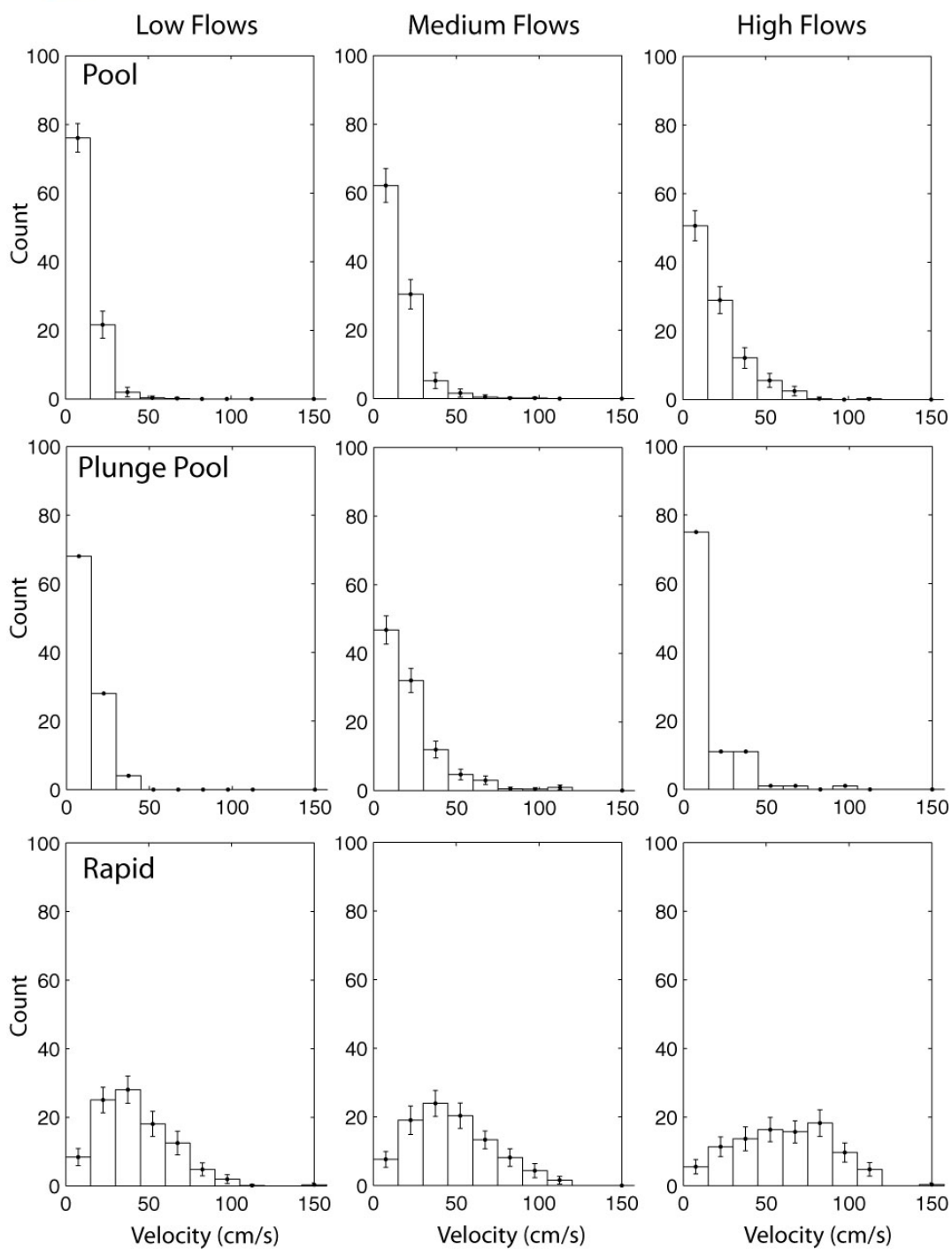
or velocity (every 15 cm/s). This analysis was conducted by grabbing 100 random samples for each flow within each HMU. This was repeated 100 times (100 bootstraps), and an average was computed within each bin along with 2 x standard deviation around this average, denoted on the figures with the bar height and error bars, respectively.











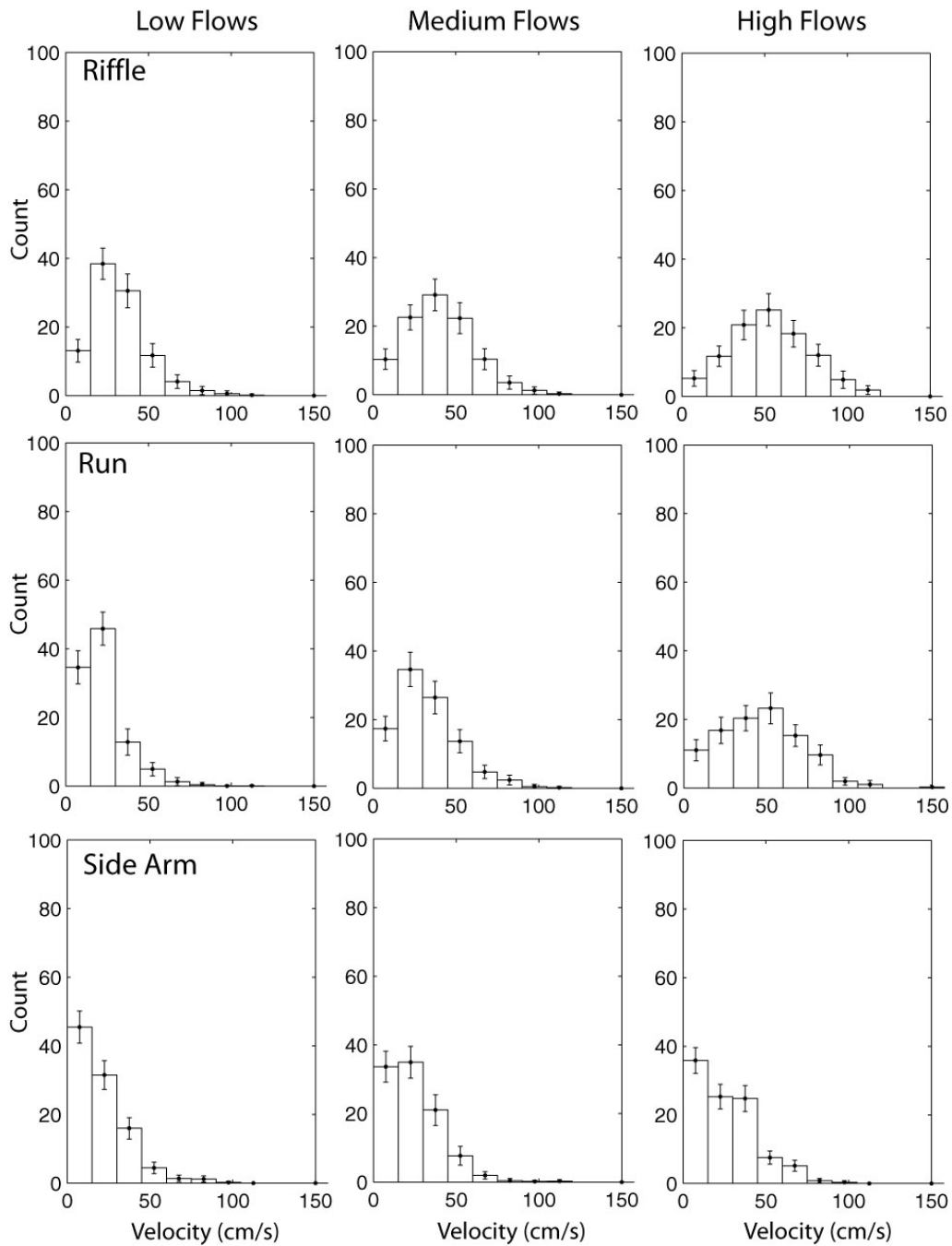


Figure 3. Velocity and depth distributions for each of 9 HMUs for each of 3 flows.

Step 3): Quantify similarities and differences in distributions across flows for a given HMU.

Differences amongst flows were quantified for each HMU using the Kruskal-Wallis nonparametric test, followed by pairwise Mann-Kendall analysis when significant differences were found. With the exception of Side Arm depths, there were significant differences between at least one flow grouping depth and velocity distributions. Pairwise analysis of depths indicated no significant differences between low and medium flows for glides, pools, and riffles nor no significant differences between medium and high flows for backwater and runs (Table 1). For velocity distributions, pairwise analysis indicated no significant differences between low and medium flows for pools and rapids, along with no significant differences between medium and high flows for pools and Side Arm HMUs (Table 2).

Table 1. Comparison of depth distributions between flows for a given HMU.

HMU	n	Mean Score			X ² Statistic	Prob>X ²
		Low Flows	Med Flows	High Flows		
Backwater	100	117.0 ^a	162.9 ^b	171.6 ^b	22.8	$p<0.0001$
Fast Run	100	93.6 ^a	146.0 ^b	211.8 ^c	93.1	$p<0.0001$
Glide	100	123.4 ^a	135.0 ^a	193.1 ^b	37.0	$p<0.0001$
Pool	100	132.2 ^a	137.8 ^a	181.5 ^b	19.4	$p<0.0001$
Plunge Pool	100	144.1 ^a	181.2 ^b	126.2 ^a	21.4	$p<0.0001$
Rapid	100	111.0 ^a	147.9 ^b	192.7 ^c	44.6	$p<0.0001$
Riffle	100	113.3 ^a	143.1 ^a	195.1 ^b	45.6	$p<0.0001$
Run	100	97.8 ^a	162.0 ^b	191.7 ^b	61.3	$p<0.0001$
Side Arm	100	135.9	150.3	165.4	5.8	$p<0.0551$
^a Classifications with the same letter are not significantly different between flows ($\alpha=0.05$ level)						

Table 2. Comparison of velocity distributions between flows for a given HMU.

HMU	n	Mean Score			X ² Statistic	Prob>X ²
		Low Flows	Med Flows	High Flows		
Backwater	100	138.8 ^a	174.9 ^b	137.8 ^a	21.2	$p<0.0001$
Fast Run	100	94.4 ^a	163.1 ^b	194.0 ^c	69.0	$p<0.0001$
Glide	100	102.1 ^a	151.9 ^b	197.5 ^c	60.9	$p<0.0001$
Pool	100	125.1 ^a	150.2 ^{a,b}	176.2 ^b	18.0	$p<0.0001$
Plunge Pool	100	141.4 ^a	191.6 ^b	118.6 ^a	40.7	$p<0.0001$

	0					
Rapid	10 0	130.0 ^a	135.9 ^a	185.6 ^b	24.8	$p < 0.0001$
Riffle	10 0	106.7 ^a	155.8 ^b	189.0 ^c	45.6	$p < 0.0001$
Run	10 0	100.3 ^a	152.1 ^b	199.1 ^c	65.0	$p < 0.0001$
Side Arm	10 0	124.4 ^a	160.3 ^b	166.8 ^b	14.1	$p < 0.0001$
^a Classifications with the same letter are not significantly different between flows ($\alpha = 0.05$ level)						

Step 4): Find a distribution fit for a given HMU within each flow.

These shape trends were further quantified by looking at the distributions under each flow condition. One random sampling of data ($n=100$) was exported to JMP and data were fit to normal and lognormal distributions. The goodness of fit statistics are summarized in Table 3-5. Because of the large number of data in each set, the distributions with $W > 0.95$ are considered normally distributed and $D < 0.1$ as lognormally distributed. Some distributions meet both these criteria, therefore the 'best fit' between the two distributions is chosen. Depth measurement approximated lognormal distributions for Fast Run, Plunge Pool, Rapid, and Riffle for at least one of the three different flows. Other depth HMUs did not approximate normal or lognormal distributions (Tables 1-3). Velocity distributions, on the other hand, typically approximated one of the two distributions. For example, Backwater, Pool, Plunge Pools, and Side Arms fit lognormal distributions for most or all flows, while Riffles fit a normal distribution for all flows (Tables 3-6). Interestingly, velocity distributions for three HMUs, including Fast Run, Glide, and Runs, shifted from a lognormal to normal distributions from low to high flows (Tables 3-6).

Table 3. Normal and Lognormal distribution fits for low flows for a given HMU.

HMU	Normal				Lognormal			
	Depth		Velocity		Depth		Velocity	
	W	P<W	W	P<W	D	P>D	D	P>D
Backwater	0.80	$p < 0.0001$	0.46	$p < 0.0001$	0.07	$p > 0.1500$	0.84	$p < 0.0100$
Fast Run	0.90	$p < 0.0001$	0.95	$p = 0.0078$	0.12	$p < 0.0100$	0.14	$p < 0.0100$
Glide	0.93	$p < 0.0001$	0.91	$p < 0.0001$	0.10	$p = 0.0312$	0.29	$p < 0.0100$
Pool	0.63	$p < 0.0001$	0.87	$p < 0.0001$	0.05	$p > 0.1500$	0.38	$p < 0.0100$
Plunge Pool	0.87	$p < 0.0001$	0.84	$p < 0.0001$	0.33	$p < 0.0100$	0.43	$p < 0.0100$
Rapid	0.86	$p < 0.0001$	0.98	$p = 0.4763$	0.06	$p > 0.1500$	0.10	$p = 0.0307$
Riffle	0.71	$p < 0.0001$	0.97	$p < 0.0716$	0.11	$p < 0.0100$	0.10	$p < 0.0100$
Run	0.67	$p < 0.0001$	0.90	$p < 0.0001$	0.08	$p = 0.1456$	0.19	$p < 0.0100$
Side Arm	0.88	$p < 0.0001$	0.84	$p < 0.0001$	0.09	$p = 0.0405$	0.30	$p < 0.0100$

Table 4. Normal and Lognormal distribution fits for medium flows for a given HMU.

HMU	Normal				Lognormal			
	Depth		Velocity		Depth		Velocity	
	W	P<W	W	P<W	D	P>D	D	P>D
Backwater	0.87	$p < 0.0001$	0.73	$p < 0.0001$	0.09	$p = 0.0466$	0.60	$p < 0.0100$
Fast Run	0.93	$p < 0.0001$	0.90	$p < 0.0001$	0.07	$p > 0.1500$	0.08	$p = 0.1046$

Glide	0.93	$p < 0.0001$	0.94	$p = 0.0007$	0.10	$p = 0.0257$	0.19	$p < 0.0100$
Pool	0.91	$p < 0.0001$	0.87	$p < 0.0001$	0.10	$p = 0.0107$	0.37	$p < 0.0100$
Plunge Pool	0.86	$p < 0.0001$	0.83	$p < 0.0001$	0.08	$p = 0.0849$	0.21	$p < 0.0100$
Rapid	0.86	$p < 0.0001$	0.96	$p = 0.0032$	0.08	$p = 0.0986$	0.11	$p < 0.0100$
Riffle	0.79	$p < 0.0001$	0.96	$p = 0.0411$	0.08	$p = 0.1324$	0.12	$p < 0.0100$
Run	0.85	$p < 0.0001$	0.95	$p = 0.0015$	0.07	$p > 0.1500$	0.09	$p = 0.0734$
Side Arm	0.87	$p < 0.0001$	0.90	$p < 0.0001$	0.07	$p > 0.1500$	0.21	$p < 0.0100$

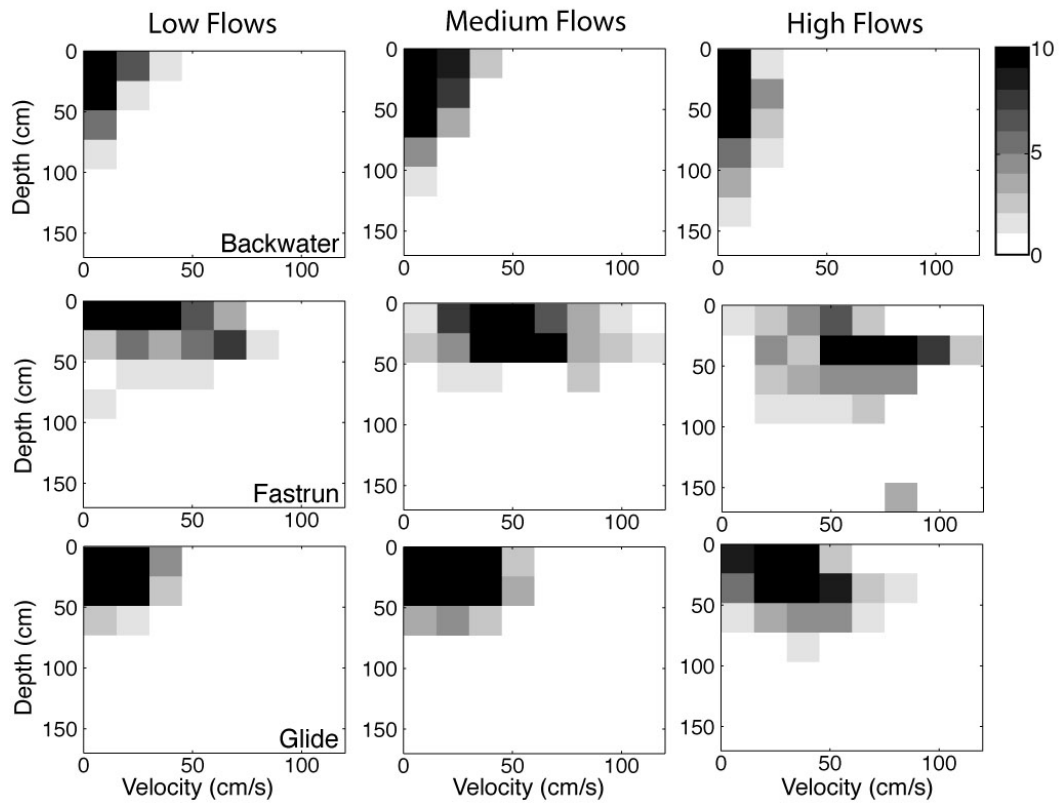
Table 5. Normal and Lognormal distribution fits for high flows for a given HMU.

HMU	Normal				Lognormal			
	Depth		Velocity		Depth		Velocity	
	W	P<W	W	P<W	D	P>D	D	P>D
Backwater	0.84	$p < 0.0001$	0.47	$p < 0.0001$	0.10	$p = 0.0211$	0.84	$p < 0.0100$
Fast Run	0.79	$p < 0.0001$	0.98	$p = 0.3170$	0.09	$p = 0.0514$	0.10	$p < 0.0100$
Glide	0.94	$p < 0.0001$	0.97	$p = 0.0886$	0.11	$p < 0.0100$	0.09	$p = 0.0494$
Pool	0.92	$p < 0.0001$	0.88	$p < 0.0001$	0.06	$p > 0.1500$	0.27	$p < 0.0100$
Plunge Pool	0.71	$p < 0.0001$	0.60	$p < 0.0001$	0.60	$p < 0.0100$	0.73	$p < 0.0100$
Rapid	0.70	$p < 0.0001$	0.93	$p < 0.0001$	0.11	$p < 0.0100$	0.12	$p < 0.0100$
Riffle	0.94	$p < 0.0001$	0.98	$p = 0.3815$	0.07	$p > 0.1500$	0.08	$p = 0.1318$
Run	0.89	$p < 0.0001$	0.97	$p = 0.0814$	0.07	$p > 0.1500$	0.11	$p < 0.0100$
Side Arm	0.87	$p < 0.0001$	0.93	$p < 0.0001$	0.08	$p = 0.1070$	0.26	$p < 0.0100$

Step 5): Generate signature plots (paired data) with the 9 HMU categories. Quantify statistical differences.

The signature plots were generated for the 9 HMU categories. The pre-specified bin spacing for either depth (every 25 cm) or velocity (every 15 cm/s) was used. One hundred random samples for each flow within each HMU were used. This was done 100 times and summed the number of times a sample fell within each paired depth-velocity bin. The total number within a bin was divided by 100 to give a total % (therefore the graybar scale represents % of total within a bin).

In order to quantify differences in signature plots, a non-parametric statistical test was used to compare distributions between low, medium, and high flows for each HMU. This test, called the Wilcoxon Signed Ranks Test takes the paired observations, computes an absolute difference between observations (depth and velocity), and compares the ranks between these distributions. Results show that with the exception of Side Arms, there are statistical differences ($\alpha = 0.05$) between flows for all other HMUs (Table 6). Some of these distributions shift with increasing flows (e.g. Backwater), while others are statistically different at either low (Fast Run, Riffle, Runs) or high (Pools) flows. The statistics confirm visual observations of the signature plots.



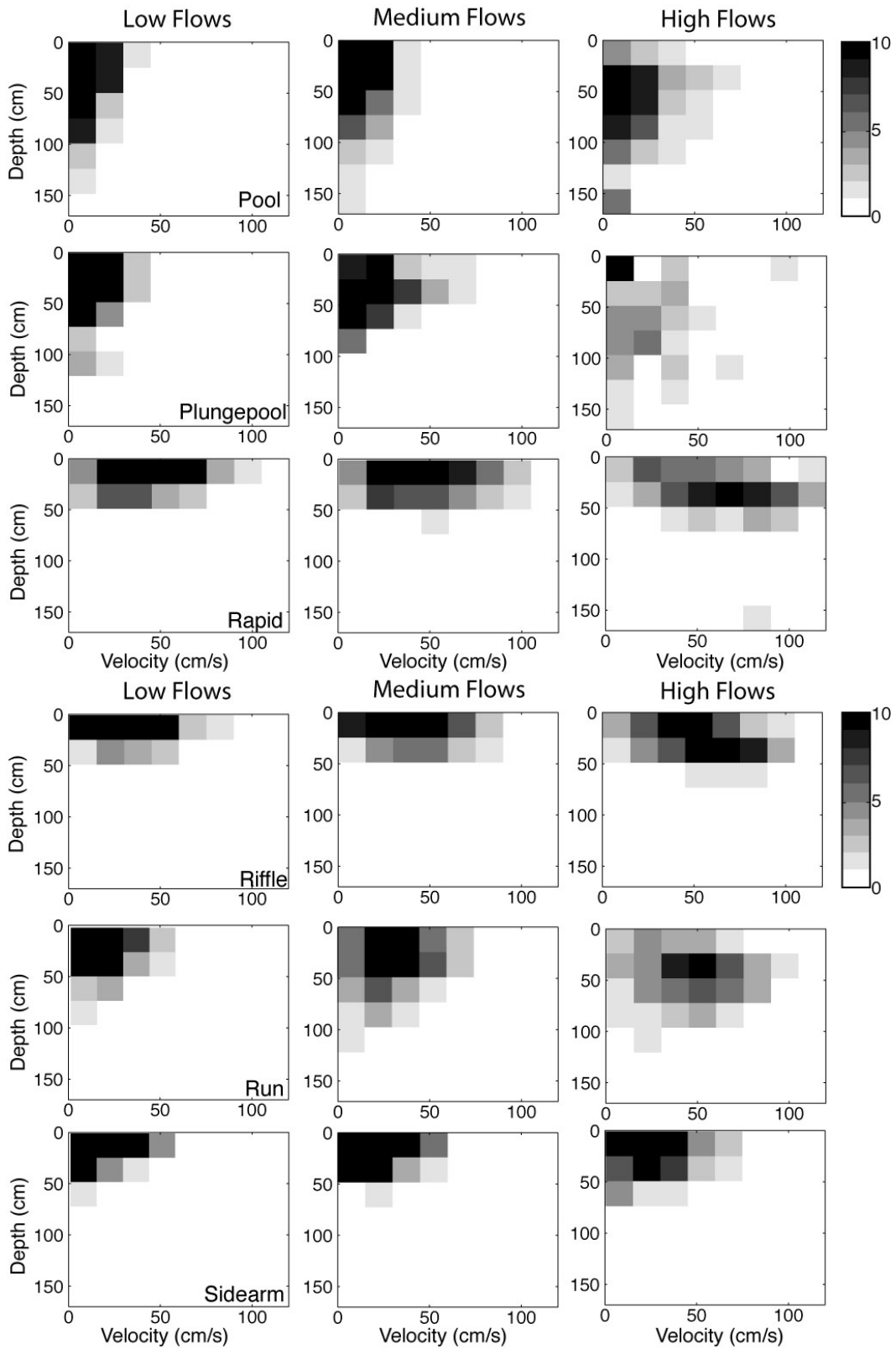




Table 6. Comparison of paired depth and velocity distributions between flows for a given HMU.

HMU	n	Mean Score		
		Low Flows	Med Flows	High Flows
Backwater	100	125.2 ^a	150.9 ^b	175.4 ^c
Fast Run	100	117.4 ^a	163.9 ^b	170.2 ^b
Glide	100	145.7 ^{a,b}	138.5 ^a	167.4 ^b
Pool	100	142.5 ^a	140.5 ^a	168.4 ^b
Plunge Pool	100	144.5 ^a	181.8 ^b	125.3 ^a
Rapid	100	144.0 ^{a,b}	140.9 ^a	166.6 ^b
Riffle	100	122.3 ^a	158.1 ^b	171.1 ^b
Run	100	125.4 ^a	168.7 ^b	157.3 ^b
Side Arm	100	142.9 ^a	149.8 ^a	158.8 ^a
^a Classifications with the same letter are not significantly different between flows ($\alpha=0.05$ level)				

Conclusions

The overall goal of this project was to use a combination of HMU signatures, field techniques, and modeling to create a new overall methodology that would provide a scientific basis for understanding thresholds of change in biotic communities as a result of changes in streamflow. We sought to find a method to simplify data collection to visual estimates of hydraulic patterns. These patterns could then be used with habitat models to predict the probable composition of fish communities as well as other aquatic communities associated with these patterns.

Our statistical analyses show that various combinations of HMUs and flows follow predictable distributions. These distributions can be used in habitat models to predict fish communities. Field data collection efforts can be significantly reduced as a result (i.e. only enough data to identify the distribution is necessary). Further, combinations of HMUs and flows also show distinct signatures (as evidenced by the signature plots) which may be used to identify habitat present in specific rivers. The effects of instream flow changes on habitat can be modeled using these signature plots.

This project resulted in a proof of concept of the modeling technique. The appropriate publication is under preparation. The next step will be to apply the method to a broader number of streams and assess its applicability.

Student Involvement

Hampshire College

Five students have worked on this project as part of Phases I and II, two paid summer interns, and three students working on independent projects throughout the school-year. Their activities are detailed below.

Miira Wirth (Summer 2006 intern)

Over the summer 2006, Miira was involved in many different stages of this project, but mainly focused on data collection and preparation. She worked on the initial reconnaissance survey of Dunbar Brook, in which we installed temperature loggers at several locations and performed a basic assessment of potential electro-fishing



sites. However, due to permitting complications we later abandoned this river and decided to electrofish and survey other more accessible rivers, as well as to mine our wealth of data previously collected from projects on other rivers. In several surveys of the Swift River and Fort River in Amherst, MA, she worked as a part of a team to electrofish and map several sites.

She used data previously collected on the Pomperaug River, CT, to help identify river-specific patterns of hydromorphologic (HMU) signatures. Her goal was to determine whether or not fish habitat corresponds to specific HMU signatures by comparing pristine conditions to full-buildout conditions. She prepared the data for this comparison for further analysis by another student of Hampshire College. This meant the preparation of datasheets using the MesoHABSIM method to determine the proportions of available habitat for several fish species on the Pomperaug River under pristine and full-buildout conditions, under several flow conditions.

Suzanne Carlson (Fall 2006 semester intern) – Project title: *'Stream Flow and Affected Fish Populations'*

Throughout the semester, Suzanne worked with Hydrosignature Project staff at Hampshire College and the University of Massachusetts to compile data and generate habitat suitability graphs for the Pomperaug and Quinebaug Rivers. She first completed a literature review to familiarize herself with the current literature. This review has been added to the literature database for the project. Her final report is currently in preparation.

Nicholas Newcomb (Spring 2007 semester intern) – Project title: *'Relating Hydraulic Patterns with Fish Communities'*

Nick's focus is the analysis of the hydrosignature patterns found in the project streams. He has also completed a literature review. Currently, he is using geographic information systems data to produce the hydrosignature plots needed for Phase II of the project. His final project and results will be completed by the end of the semester.

Nicholas Newcomb (Fall 2007 semester intern)

Nick continued to work on his project during the fall semester. He also compiled additional data for the Phase II modeling.

Paula Mouser (Summer 2007)

Paula used her background in statistics to perform the statistical analyses of the HMU data. She identified distributions for the HMUs and flows and compared the distributions. She performed multiple statistical tests including histogram analysis, cluster analysis, pairwise comparisons, etc.

Julie Groff (Spring 2008 semester intern)

Julie helped organize data and prepare data sets for modeling.

University of Massachusetts

Daniel Sisí Maestre, Eva Alfonzo Corzo, Manuel Moreno Ruiz-Poveda and Roberto Martínez Romero are four graduate students of forestry from Madrid Polytechnic in Spain who helped in data collection and analysis.

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3. Environmental Behaviors of Engineered Nanoparticles in Water (USGS 2007MA73B)

Principal Investigator: Baoshan Xing

Start Date: 3/1/2007

End Date: 2/28/2009

Reporting period: March 1 2007 – February 29 2008

Keywords: Nanoparticle; sorption, suspension; toxicity, environment

Problem Statement: Knowledge of engineered nanoparticles in water is critical for evaluating their environmental fate, exposure, toxicity and risk. The research objectives this year were:

- 1) To characterize the physical and chemical properties of nanoparticles and their dynamic aggregation behaviors under different aqueous conditions;
- 2) To examine the adsorption and desorption of toxic pollutants and DOM by nanoparticles;
- 3) To evaluate the toxicity of several nanoparticles.

Methodology: Batch sorption techniques, liquid scintillation counting, HPLC detection, microbial tests, TEM and SEM examinations, seed germination tests.

Principal Findings and Significance:



Our preliminary data show that nanoparticles are toxic to tested microbes and plants; more toxic than their corresponding bulk materials. This is significant because these particles may pose risk to different ecosystems once released to the environments. Our data also showed that the nanoscaled aluminum oxides adsorbed more dissolved organic matter (DOM) and phenanthrene than the microscaled particles. In addition, different DOM samples could coat on carbon nanotubes (CNTs), some significantly reduced sorption of organic contaminants by CNTs, while others have minimal effect. These results are expected to help understand the interaction between CNTs and organic contaminants and environmental behavior of CNTs.

Publications and Conference Proceedings:

Scientific Journals:

- Wang, X.L., J.L. Lu and B. Xing, 2008. Sorption of organic contaminants by carbon nanotubes: Influence of adsorbed organic matter. *Environ. Sci. Technol.* 42:3207-3212.
- Iorio, M, B. Pan, R. Capasso and B. Xing, 2008. Sorption of phenanthrene by dissolved organic matter and its complex with aluminum oxide nanoparticles. *Environ. Pollut.* (in press).
- Pan, B., D.H. Lin, H. Mashayekhi and B. Xing, 2008. Adsorption and hysteresis of bisphenol A and 17 α -ethinyl estradiol on carbon nanomaterials. *Environ. Sci. Technol.* (accepted).

Conference Proceedings:

- Lin, D.H. and B. Xing, 2008. Phytotoxicity of zno nanoparticle: inhibition of ryegrass growth. Preprints of Environ. Chem. Div. Extended Abstracts of the 235th ACS national meetings. 48(1): 276-280.
- Mashayekhi, H., W. Jiang and B. Xing, 2008. Metal oxide nanoparticles show toxicity to bacteria. Preprints of Environ. Chem. Div. Extended Abstracts of the 235th ACS national meetings. 48(1): 326-328.
- Pan, B. and B. Xing, 2008. Sorption of endocrine disrupting chemicals on carbon nano materials." Preprints of Environ. Chem. Div. Extended Abstracts of the 235th ACS national meetings. 48(1): 206-208.
- Wang, X.L. and B. Xing, 2008. Dissolved organic matter affects sorption of organic contaminants on carbon nanotubes. Preprints of Environ. Chem. Div. Extended Abstracts of the 235th ACS national meetings. 48(1): 220-223.

Student Support:

Hamid Mashayekhi, Ph.D., Department of Plant, Soil & Insect Sciences, UMass Amherst.

4. Development of a Standardized Protocol for Fish Bioassays Detecting Estrogenic Exposure (USGS 2007MA74B)

Principal Investigators: Lauren Moffatt, Kathleen Arcaro

Start Date: 3/1/2007

End Date: 2/29/2008

Reporting period: March 1 2007 – February 29 2008

Research Category: Biological Sciences

Focus Category: Methods, Non Point Pollution, Wastewater

**Problem and Research Objectives:**

Endocrine disrupting compounds are of increasing concern in waterways throughout the Northeast. Specifically, estrogenic contaminants have been detected downstream of agricultural operations, industrial discharges, and even municipal wastewater treatment facilities. Concern regarding the feminization of fish and wildlife species has led to the demand for sensitive, accurate, and reliable means to detect estrogenic activity in water samples. Fish models are ideal for examining potentially polluted waterways because fish are directly exposed to and quickly concentrate aquatic contaminants. In concert with the use of molecular techniques, specifically the analysis of changes in gene expression, fish bioassays can be a sensitive indicator of estrogenic pollution. Although vitellogenin is a well established biomarker of estrogenic endocrine disruption in male fish models, there is a great deal of variability in the assay design used by investigators measuring its induction. Despite the importance of vitellogenin as a biomarker, there has been no published study in which the parameters that affect vitellogenin expression, including length of exposure, number of fish per tank, volume of water per tank and frequency of water changes have been systematically investigated. Therefore, investigating the effects of experimental variables on bioassay outcome will help to characterize the assay with respect to its utility and limitations, and may aid in establishing a standard protocol resulting in a rapid and sensitive bioassay. The goal of this work was to characterize the sensitivity of the fish vitellogenin bioassay to changes in experimental design.

Methodology:

Male Japanese medaka (*Oryzias latipes*) were exposed in the laboratory to a range of environmentally detected concentrations of 17β -estradiol (E2) over a 96 hour time course. Water changes for all exposures occurred every 24 hours along with new chemical (or 1:10,000 or 1:1 million DMSO solvent control, depending on dilutions used to achieve exposure concentrations) addition to ensure constant exposures. At given time points, fish were anesthetized in buffered 0.5% tricaine methanesulfonate (MS-222) until immobile, blotted dry and weighed, and then decapitated immediately prior to dissection. Tissues removed (brain, liver, and gonad) from each fish (1 fish = 1 sample) were placed immediately into RNAlater solution and stored at 4°C until RNA isolation, or archived at -20°C for later use. High quality RNA was isolated from liver tissue using TRI-Reagent and quantified before being used in real time RT-PCR reactions along with gene-specific primers to quantify expression of vitellogenin and housekeeping gene mRNA. Vitellogenin quantities were normalized to the housekeeping gene and a combination of t-tests ($p < 0.05$) and one way ANOVA ($p < 0.05$) were used to determine statistically significant induction of vitellogenin over controls. Experimental parameters that were manipulated (independently or in combination) in a series of experiments included the specific estrogenic compound (E2, 17α -ethynyl estradiol EE2, or bisphenol A), the concentration of compound (1, 10, 100, or 1000pM), the length of exposures (24, 48, 72, or 96 hours), the volume of water per 2 fish used in exposure tanks (0.5L, 1.0L, or 2.0L), the lag/deposition time between chemical exposure and dissection/analysis (immediate, 24, 48, or 72 hours), and feeding status of fish (fed during exposure as in colony, versus unfed). These variables were examined with respect to their effects on vitellogenin mRNA induction.



Principal Findings and Significance:

The medaka vitellogenin mRNA bioassay was found to be sensitive and reliable in detecting levels of estrogens as low as 100pM (with environmentally detected levels being around 600pM), with the exception of bisphenol A which was undetectable via vitellogenin induction at the range of concentrations tested. This is not entirely surprising considering the literature reports of bisphenol A's very weak estrogenic capabilities. Vitellogenin induction typically occurred in as little as 24 hours and was significant over controls at 48 hours. This assay is therefore rapid and sensitive. It was found that changing the volume of water in which the fish were exposed to E2 did not affect the outcome of the assay in the range of volumes that we tested in this static system. However, it was determined that vitellogenin mRNA levels that have been induced by a short exposure to E2 will begin to decline after 24 hours of depuration or absence of estrogenic contamination, and will continue to decrease over time. This indicates that samples should be processed in a rapid manner after exposure occurs. It was also found that although not feeding the animals during exposure did not significantly reduce the vitellogenin response, the expression of some genes involved in energy balance and stress response were altered, indicating longer exposures and therefore deprivation of food could result in a change in vitellogenin response, or reproductive response entirely. Perhaps most importantly, it was found within the first set of experiments performed that the handling and presentation of gene expression data can alter the interpretation of the outcome. Specifically, data presented as fold change (obtained from dividing the relative expression values of treated animals by the expression values in control animals) did not typically resemble the data presented as relative quantities with both treatment and control displayed side by side. The reason for this is that although baseline, control levels of vitellogenin in male fish are all very low (hundreds to thousands fold lower than in animals treated with 100pM or higher of E2), there is a substantial amount of individual animal variability at those low levels. This variability, which is likely biologically meaningless, can be by tens to almost hundreds fold, thus affecting the fold change data where the denominator becomes highly variable. Therefore, it was demonstrated that in this assay the more appropriate presentation of the data is through showing relative quantities of vitellogenin expression in both treated animals and control rather than fold change. The work performed here has helped determine the sensitivity of the medaka vitellogenin mRNA assay to variability in experimental parameters. Both the flexibility and limitations of the assay have been characterized. This work has shown that the outcome of the assay is sensitive to some variables and not to others, however careful consideration must still be given to the design of such experiments because of the nature of the assay. In other words, the model is shown to be innately sensitive with respect to the accumulation of pollutants that occur in fish and the sensitivity of real time RT-PCR, making it a good sentinel of low levels of estrogenic contaminants, but a tool that must be handled appropriately to obtain meaningful and reliable results. Furthermore, the handling and interpretation of the data must be managed appropriately to gain the most biologically and environmentally relevant information.

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Publications and Conference Presentations

Dissertations

Moffatt Lauren, 2008. "The Development and Characterization of Fish Gene Expression Bioassays for Detecting Aquatic Endocrine Disruptors and Other Emerging Contaminants", Ph.D. Dissertation, Department of Veterinary and Animal Sciences, University of Massachusetts, Amherst, MA 01003, 261pp.

Poster Presentations

Moffatt Lauren and Kathleen Arcaro, 2007. "Quantitative Biomarkers of Estrogenic Exposure in Fish; Gene Expression Bioassays in two Model Species", Massachusetts WRRC 4th Annual Meeting (April 9th, 2007, Amherst, MA) and American Water Resources Association Specialty Conference on Emerging Contaminants (June 25th-27th, 2007, Vail, CO).

Publications in Preparation

Moffatt Lauren and Kathleen Arcaro, 2008. Characterizing Fish Gene Expression Bioassays for Detecting Estrogenic Contaminants: Parts I and II, Manuscripts in preparation.

Student Support

Lauren Moffatt, Ph.D., Department of Veterinary and Animal Sciences, University of Massachusetts, Amherst, MA.

Notable Achievements and Awards

- Massachusetts WRRC 4th Annual Meeting Best Student Poster Award, April 2007
- UMass Graduate School Travel Grant, 2007



5. Acid Rain Monitoring Project (MADEP)

Principal Investigator: Marie-Françoise Walk, MA Water Resources Research Center, UMass Amherst

Start Date: July 1, 2007

End Date: June 30, 2008

Reporting period: July 1 2007 – June 30 2008

Keywords: Acid Deposition, Surface Water Quality, Volunteer Monitoring

The Acid Rain Monitoring project continued for the 6th consecutive year after an 8 year hiatus preceded by 10 years of consecutive sampling. About 150 sites (mostly streams) were sampled by volunteer collectors and tested for pH and alkalinity by volunteer labs. Of those, 26 long-term sites were analyzed for the full suite of major cations and anions. The data from 1983 to 1993 were previously analyzed for trends relevant to acid rain control. With sufficient new data on lakes and streams collected over the past 4 years, changes resulting from passage of state and federal clean air act revisions can be evaluated. These analyses are in process and should provide important evidence in the ongoing debate about clean air standards.

The more than 43,000 records of water chemistry for Massachusetts' lakes and streams, now covering 1983-2008, are posted on a web site in a searchable and downloadable form so that additional data analyses specific to the user may be conducted (<http://umatei.resuo.ads.umass.edu/armproject1/>). A report on trends of Acid Precipitation on Massachusetts Surface Waters is expected to be published in 2009.

Students Supported:

1 BS student in Economics at UMass Amherst.

1 PhD student in Chemistry at UMass Amherst.

Information Transfer Program

1. Water Resources Conference 2008

Principal Investigators: Paula Rees, Director, and Marie-Françoise Walk, MA Water Resources Research Center, UMass Amherst

Start Date: 3/1/2007

End Date: 2/29/2008

Reporting period: March 1 2007 – February 29 2008

Descriptors: Conference, Water Resources, New England

The Water Resources Research Center organized the fifth annual Water Resources Research Conference: Integrating Water Resources Management. While the conference took place in April, most of the work for this conference was accomplished in the reporting period. The Cooperative State Research, Education,



and Extension Service New England Regional Program again cooperated in planning the conference. Six co-sponsors helped underwrite the cost of the conference. Attendance increased from last year, to 144. Thanks to an increased sponsorship from the Massachusetts Department of Environmental Protection, attendance and presentations by DEP personnel were greatly increased this year. The Steering Committee was expanded to include many non-UMass professionals. Thirty posters were presented and there were 36 paper platform presentations in three concurrent sessions. The presentations were grouped into four tracks subdivided into three sessions each:

Water Resources Management and Planning

Water Quality and Enforcement
Effective Water Management Regulations
Water Resources Planning

Water Issues in the Field, Lab, and Classroom

Fish: Water Resources Management Indicator
Water Research and Climate Change
Case Studies in Water Resources Education

Stormwater Challenges

Low Impact Development
Stormwater Best Management Practices
Stormwater Monitoring and Management

Identification, Assessment, and Remediation

Surface / Ground Water Interactions
Contaminants in Water
Wastewater Issues

The Keynote Address was given by Ira Leighton, Deputy Regional Administrator for USEPA New England on New Developments in Stormwater Policy and Remediation. Follow-up communications with Mr. Leighton have led to the draft of stormwater modeling proposals at the WRRC.

2. Innovative Stormwater Technology Transfer and Evaluation Project (MADEP)

Principal Investigator: Jerry Schoen, MA Water Resources Research Center

Start Date: 1/1/2008

End Date: 6/30/10

Reporting period: July 1 2007 – June 30 2008

Descriptors: Stormwater, Water Quality, Non-point Source Pollution

The Massachusetts Dept of Environmental Protection (MADEP) awarded WRRC a two and a half year grant to continue a previous project WRRC staff had contributed to in FY'05 and FY'06. The goal of this project is to provide technology transfer information about innovative stormwater Best Management Practices (BMP) to MADEP, conservation commissions, local officials, and other BMP Users. The project



maintains and updates the database already in place (www.mastep.net) and will continue to expand the database by adding information pertaining to at least twenty new proprietary BMPs and at least ten conventional and ten Low Impact Development BMPs. In the first six months of this project, WRRC staff met with the Massachusetts Stormwater BMP working group to get input on revision of BMP category rating system and redesigned the rating system.

Timeline priorities for year 1 of the project were also identified with the help of DEP, EOEA staff and external advisors (e.g. Mass Highways staff, vendors).

3. Stream Continuity Project

Under a memorandum of understanding with UMass extension, WRRC staff worked to coordinate volunteers and manage the database for the Stream Continuity Project, a study looking at stream crossings and their status at creating barriers for fish and wildlife passage.

4. Other Information Transfer/Outreach

WRRC maintains a web site at www.umass.edu/tei/wrrc and a listserv of 1044 members to inform the public of latest water resources research news.

Volunteer Monitoring

For the EPA-funded Tri-State Watershed Initiative in the Connecticut River watershed, WRRC leads a volunteer bacteria monitoring program covering 25 sites from Hanover NH to the Connecticut border. The Center is also monitoring the effects of nutrient- management BMPs on phosphorus levels in the Mill River, Hadley.

The quality-control program for volunteer-monitoring groups continued for pH, alkalinity and dissolved oxygen through the Environmental Analysis Laboratory. Analytical services were provided for ten Massachusetts and Connecticut volunteer groups.

Information Technology

WRRC is involved in three projects using information technology for environmental research, teaching and outreach. In all three projects, WRRC is partnering with the UMass Center for Educational Software Development. 1) An eQuest program, funded by the Department of Elementary and Secondary Education, engages Athol middle schoolers in learning phenology and biodiversity concepts by exploring natural and built areas of the North Quabbin region, aided by location-aware handheld computers and web-based mapping programs such as Google Earth. This project is a collaboration among WRRC, the Athol-Royalston Regional School District, Harvard Forest, and the Millers River Environmental Center. 2) A UMass Academic Technology grant is being used to redesign three plant identification courses to incorporate handheld computers and electronic field guides. Collaborators include John Ahern (LARP), Karen Searcy (biology), and Robert Stevenson (biology, UM Boston). 3) For the EPA-funded Tri-State Watershed Initiative in the Connecticut River watershed, the Center is developing a Google-Earth-based virtual tour of the watershed and handheld-computer mobile tours of selected areas where environmental restoration work is occurring in the watershed.



Other Activities

1. Environmental Analysis Laboratory

Reporting period: July 1 2007 – June 30, 2008

The Environmental Analysis Laboratory (EAL) was created in 1984 by WRRC to assist the Acid Rain Monitoring Project (ARM) by analyzing more than 40,000 samples for a suite of 21 parameters. Since 1988, the Lab has provided services to a wide range of off-campus and on-campus researchers. EAL provides chemical analysis of water, soils, tissue, and other environmental media for University researchers, public agencies, and other publicly-supported clients. The EAL conducts a wide variety of analyses to support environmental research, management, and monitoring activities. EAL provides high quality analytical services for inorganic substances in water including nutrients, inorganic anions, and metals and has especially distinguished itself in the analysis of trace levels of phosphorus.

In this past year, EAL continued to provide laboratory support for the Acid Rain Monitoring Project, including a quality-control program for pH and alkalinity and analytical determinations for a suite of 15 parameters. The quality-control program for volunteer-monitoring groups continued for pH, alkalinity and dissolved oxygen. Analytical services were provided for ten Massachusetts and Connecticut volunteer groups, the town of Barnstable, three university researchers, the Department of Environmental Health and Safety and Lycott Environmental, Inc. A new collaboration with the Chemistry Department was initiated, with Dr. Julian Tyson and his lab now responsible for sample analyses and new methods development.

The new management structure of the lab provides a unique opportunity to provide both the campus community and others with specialized methods development as well as basic analytical services. This includes an ability to analyze media other than water and soil, and is a significant expansion of capabilities in comparison to the original lab. There is the potential for unique graduate thesis components to result from method development requests. It establishes a set fee schedule and central contact point for inquiries, and avoids PI to PI requests for "favors" in terms of running analyses. In so doing, it strives to establish a higher degree of analytic quality for methods development and special requests. In summary, potential opportunities include:

- Methods development
- Potential for graduate thesis components
- Centralized point of inquiry for campus
- Better control of quality control for across campus analytical requests.
- Undergraduate research opportunities.



2. Working Groups

Reporting period: July 1 2007 – June 30, 2008

The WRRC has been participating in the coordination of interdisciplinary working groups on themes such as "Water" and "Environmental Contaminants." Each year the working groups help identify several seminar speakers and host their visit as part of The Environmental Institute (TEI) sponsored seminar series.

The Fall 2007 TEI Lecture series theme was "Water Sustainability" and featured several topics of interest to the Water Working Group:

- Shane Snyder, Research Development Project Manager, Southern Nevada Water Authority. Emerging Contaminants and Water Quality: Endocrine Disruptors and Pharmaceuticals in the Environment.
- Ken Conca, Professor of Government and Politics, University of Maryland. Governing Water: Understanding the Global Water Crisis.
- Charles Vorosmarty, Research Professor, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire. Global Hydrology: Lessons from the U.S. Northeast Corridor.
- Mark Person, Professor of Hydrology, New Mexico Institute of Mining and Technology. Offshore Freshwater: A Potential Resource for Coastal Areas. Pleistocene Hydrogeology of the Atlantic Continental Shelf in New England.

The Spring 2008 TEI Lecture Series theme was "Emerging Technologies and the Environment" and featured three speakers:

- Pedro J. Alvarez, George R. Brown Professor of Engineering at Rice University. Nanotechnology: Environmental Implications and Applications.
- John A. Stankovic, BP America Professor, University of Virginia. Wireless Sensor Networks: Global Scale Environmental Monitoring. Arctic to Zebras.
- Michael L. Knotek, Knotek Scientific Consulting. The Role of Genome Science in Bioenergy, Carbon Cycling, and Environmental Remediation.

During each visit, Water Working group members had opportunities to interact with the speaker to discuss emerging issues and trends in research and education. These interactions have assisted in proposal development and will hopefully lead to future collaborations.

In addition, members of the working groups worked on two IGERT proposals during the reporting period:

- IGERT: Understanding Manufactured Nanomaterials in the Environment through Research and Science Education.
- IGERT: Sensing, Modeling and Policy for Water Sustainability.

The water sensing IGERT was invited to the full proposal stage. In addition, working group faculty collaborated on proposals to the NSF Cyber-Enabled Discovery and Innovation (CDI) program. Further, several faculty contributed summer workshop ideas for a feasibility study evaluating the viability of the University hosting summer workshops for high school students interested in water and the environment.

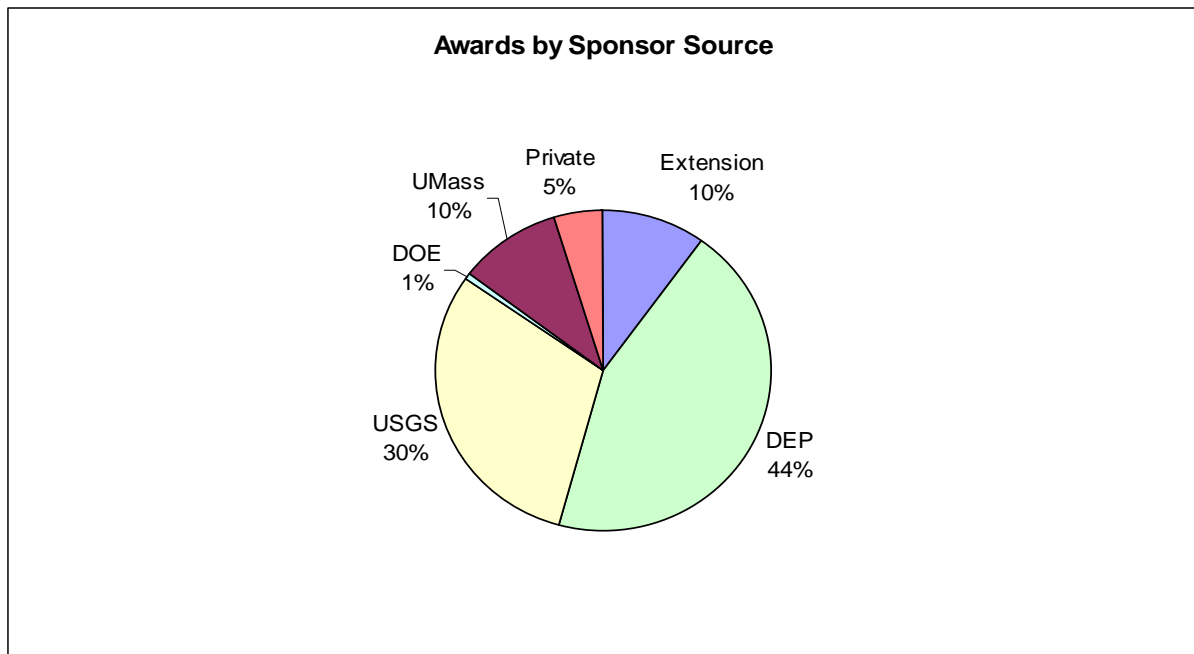


Financial Overview

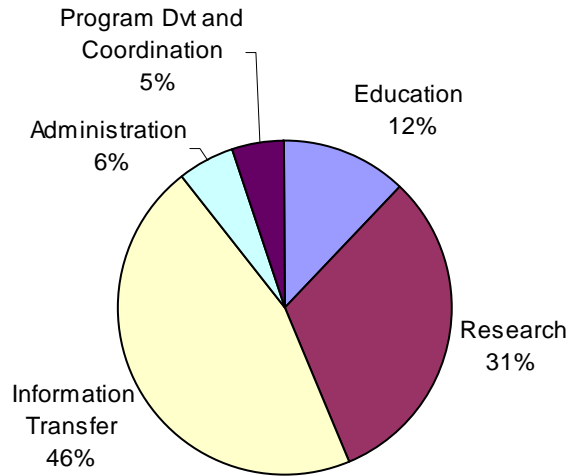
Center revenues come strictly from grants and contracts. The University of Massachusetts supports the half-time Director's salary and also provides physical facilities.

Total revenues amounted to \$301,178:

USGS 104B:	\$91,767 broken down as follows:
	\$24,988 Xing research project
	\$24,900 Jackson research project
	\$4,917 Arcaro research project
	\$16,806 Administration
	\$20,156 Conference
Extension (MassWWP)	\$30,000 Extension-WRRC MOU
DEP (Stormwater Project)	\$83,000
DEP (Acid Rain Project)	\$50,000
DOE (Equest)	\$ 2,000
UMass (Director)	\$30,000
Lab Revenues (EAL)	\$ 4,165
Conference Revenues	\$10,246



Awards by Category



Awards by Sponsor Type

