Introduction

The Connecticut Institute of Water Resources is located at the University of Connecticut (UCONN) and reports to the head of the Department of Natural Resources Management and Engineering, in the College of Agriculture and Natural Resources. The current Director is Dr. Glenn Warner, and the Associate Director is Dr. Patricia Bresnahan.

Although located at UCONN, the Institute serves the water resource community throughout the state. It works with all of Connecticut's water resource professionals, managers and academics to resolve state and regional water related problems and to provide a strong connection between water resource managers and the academic community.

The foundation for this connection is our Advisory Board, whose composition reflects the main water resource constituency groups in the state. IWR staff also participates on statewide water-related committees whenever possible, enabling our Institute to establish good working relationships with agencies, environmental groups, the water industry and academics. Our seminar series, a long-standing Connecticut IWR tradition, provides a unique opportunity for the water resource professionals and interested members of the public in our small state to gather, be informed, and become better acquainted.
Research Program Introduction

The USGS 104B program is the financial core of the CT IWR. The Institute does not receive discretionary funding from the state or the university, although it does receive approximately $25K per year as match towards the salary of the Associate Director.

The majority of our 104B funds are given out as grants initiated in response to our annual RFP, with the majority of those funds going to research projects. When selecting projects for funding, the Institute considers three main areas: 1. technical merit, 2. state needs and 3. CT IWR priorities (use of students, new faculty, seed money for innovative ideas).

In addition to its 104B program, the Institute conducts externally funded projects. Three of these projects that were active during the 2008-2009 reporting period include:


NOTABLE ACHIEVEMENT: DROUGHT EMERGENCY PREPAREDNESS

Within the State of Connecticut there is a growing recognition that planning water policy and management need to be supported by sound science. Questions related to water allocation and basin water budget status are emerging as critical needs. The CTIWR has actively addressed these needs in recent years through its information transfer program, and in the process developed a network of cooperators and supporters. In 2007, this network came together to ask the state legislature to provide financial support to our Institute. As a result, our Institute received a $200K state appropriation for water basin planning.

One of the projects supported by these funds was the "Pomperaug Water Allocation Planning Study." While the Connecticut Water Planning Council and the state legislature have endorsed the concept of watershed based water allocation planning, currently no authorized process for such planning exists. To study the feasibility of making water allocation decisions at the basin scale, the CT Institute of Water Resources partnered with the Pomperaug River Watershed Coalition to conduct a tabletop simulation of a severe drought in that basin.

Between 2002 and 2005, the State of Connecticut weathered two droughts, although these pale in comparison to the severe drought that occurred during the 1960’s. In the 40 years since that extreme drought, the state has experienced very intense commercial and residential development, all taxing state water basins. But because a drought affects multiple towns with varying water supplies and infrastructure, planning for and managing a severe drought will require the cooperation across geographic boundaries and governmental jurisdictions.

The simulation exercise brought together over 40 federal, state and local officials (USGS, CT OPM, CT DPH, CT DEP, town selectmen, water companies, NGOs) for a one day workshop. The “after action” report
submitted by the Coalition outlined the need for an emergency management plan that addresses safety and health concerns, instream flow needs, as well as town boundary issues. A white paper, in progress, will outline recommendations for a basin-based political process for long term water allocation policy and planning.

This study has raised the awareness of the state’s water managers of the need for coordinated, cross-jurisdictional water allocation planning in general, and has made the emergency management community aware of the need to develop plans for managing long-term severe drought. In particular, the Connecticut Department of Emergency Management and Homeland Security is interested in using this study as a basis for conducting similar exercises around the state.
Development and evaluation of a multi-dimensional spatially and temporally dynamic mesohabitat classification model for stream management and water flow allocation planning in southern New England streams

Basic Information

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Publication
Title: Development and evaluation of a multi-dimensional spatially and temporally dynamic mesohabitat classification model for stream management and water flow allocation planning in southern New England streams

Statement of regional or state water problem: Connecticut, through recent legislation, has entered a process to evaluate the allocation of stream waters between “human” and “environmental” uses. The State is seeking a better understanding of the biological and geomorphological significance of flow regimes to protect stream biota and ecosystem functions for all streams in the state. The question of how much water stream inhabitants really need has most often been answered using hydraulic models which cover a relatively short reach of stream. Such models make assumptions that modeled reaches are representative and inference from results are typically limited in space. To use this modeling approach for all streams in the state is essentially cost prohibitive. Connecticut has begun to evaluate the flow requirements of stream biota using a newer modeling approach based on mesohabitats (Parasiewicz 2001), which are also known as channel geomorphic units and hydraulic habitat units, among other names, but represent what are commonly known as pools, riffles, glides, etc. (Figure 1). The mesohabitat modeling approach covers a longer reach of river for the same cost and because of the larger spatial scale may be more transferable among similar streams. Mesohabitats are known to be important to the stream biota and have been shown to support distinct biotic assemblages (Rabeni and Jacobson 1993a, Peterson and Rabeni 2001b, Rabeni et al. 2002). While pools, riffles, and runs seem easy enough to identify, mesohabitats are flow dependent (i.e. they get bigger and smaller with changes in stream stage) and are more numerous in type than one might initially suspect. Pools, riffles and runs are more correctly categories of mesohabitats, for example pools have been subdivided into obstruction, lateral, bluff, plunge, and beaver pools. Not all regions have streams with the same compliment of mesohabitats and regional variant classification schemes are numerous. Researchers in the Rocky Mountains use a scheme with different mesohabitats than those in the Ozark Plateaus region and again different than those in the southern Appalachian Mountains. Connecticut needs a regionalized southern New England classification scheme for mesohabitats if it is to defensibly use mesohabitats to determine the effects of flow diversion on stream biota habitat quantity. To address this need, a sound, scientific empirically-based investigation of geomorphic, hydraulic and biological mesohabitat distinctness in Connecticut should be prerequisite to the development and use of a classification system to inform management decisions. That is to say, definitions of physically distinct mesohabitats must be created and stream biota must show
differences in assemblage structure and composition within these mesohabitats to be a meaningful basis for decision making.

**Statements of results or benefits:** A physically distinct and biologically meaningful classification of mesohabitats for southern New England would result in the potential improvement of mesohabitat modeling efforts underway to quantify the effect of flow diversions on habitat quantity for stream biota. In addition, the classification scheme would serve to increase general understanding of stream ecosystems in the region. Future research and monitoring would benefit from the ability to stratify sampling among mesohabitats, increasing the quality of data and interpretations. Further, the evaluation of the classification scheme will also provide detailed information documenting the patterns of mesohabitat characteristics and size changes with varying discharge. This pattern of change is an extremely important underpinning of comparisons between high-water and low-water modeling scenarios. Furthermore, the significance of hydrogeomorphic classifications becomes more powerful when measurements are representative of the complete biologically significant variability within mesohabitats (e.g., three-dimensional vs. one-dimensional velocity measurements).

Instream habitat classification has multiple management implications that require an ability to predict both the trajectory of the habitats themselves and the biota that live within the habitats. Classifications systems will have more utility if they have been verified biologically. It could be that a dozen or so physically distinct mesohabitats can be statistically defined in southern New England, but biologically only half of those may house distinct biotic assemblages. This information would inform managers that a collapsed set of mesohabitats may be important to conservation. Research has emphasized applications of minimum instream flow determination on regulated rivers (Newson and Newson 2000, Parasiewicz 2001), routine biological sampling (Poole et al. 1997, Rabeni 2002), and river rehabilitation and restoration (Sear 1994, Kemp et al. 1999). Our proposed empirical research would greatly improve the capability of mesohabitat models to contribute to these important management challenges.

Current mesohabitat delineation techniques in southern New England have to date been based on visual identification and limited (in both number and complexity) quantitative field measurements. Our proposed research will enable an unbiased, statistical delineation of mesohabitats based on objective hydrogeomorphological criteria. This refinement of mesohabitat classification will provide foundational background and definitions that will be helpful to the modeling efforts that are already in place.

**Nature, scope, and objectives of the project, including a timeline:** The proposed research is an integrated empirical field data collection and modeling study that will produce both a biologically meaningful classification of mesohabitats for southern New England streams and a model to predict spatio-temporal changes in these mesohabitats under variable streamflow conditions. The specific objectives of this research are to:

1) Collect hydraulic characterizations of mesohabitat channel units from three streams and use statistical classification to create a scheme of physically distinct mesohabitats based on channel morphology, flow depth and Froude number, and three-dimensional flow variability with stage
2) Develop a hydraulic model which demonstrates the spatio-temporal patterns of channel units as they vary with discharge
3) Collect macroinvertebrate and fishes (abundance, size classes, and species identity) from mesohabitats and statistically determine biological distinctness among channel units

The proposed research project began with intensive geomorphologic and hydraulic field data collection during summer 2006. Macroinvertebrate and fish sampling occurred during the summer and fall of 2006. Field work is complete. Data analysis of fish communities is complete. Data analysis of macroinvertebrates and hydraulic model development have become problematic as cooperating personnel have left the University with task left to be completed.

Methods, procedures, and progress: Three streams in southern New England were used for data collection, both physical and biological. Study reaches, one per stream, were 1-2 km in length and chosen to encompass heterogeneous habitat conditions. Streams sampled were the Willimantic River, the Still River (Farmington watershed) and Elldredge Brook.

Though mesohabitat spacing varies widely in nature, we attempted to sample 25 mesohabitat units within each study system. The geomorphology of each study reach was surveyed in detail using electronic total station surveying, sediment substrate characterization, and microhabitat unit mapping. Hydraulic flow fields were characterized at low and moderate flows using a YSI FlowTracker acoustic doppler velocimeter (ADV). The combined geomorphic and hydraulic data will be used to generate a two-dimesional model of the study reaches using a well-established pre-packaged modeling program (River2D). This modeling software, when combined with our statistically-generated mesohabitat definitions (criteria) will enable quantification of mesohabitat aerial change with changing flow stage, as well as permit quantification of hydraulic variability in different mesohabitat units at multiple stages.

Macroinvertebrates and fish were collected from geo-referenced locations in the study reaches and will be later delineated to specific mesohabitats to generate species assemblage data for particular mesohabitats. Macroinvertebrates were sampled using a kick-net stream benthos sampler and fish with backpack and push-barge electrofishing gear. Fish species assemblages were compared among mesohabitat samples using
principal component analysis and hierarchical cluster analysis (Peterson and Rabeni 2001b).

Results from the fish assemblage data analyses suggest that perhaps as few as two assemblages of fish occur in reaches of Connecticut streams. These two assemblages appear to relate to “fast-water” and “slow-water” habitats (Figure 3). While only part of the ecosystem, this may foretell that mesohabitat-level instream assessments using fish may be able to use a much simpler classification than those recently employed. Identification of invertebrates is a current priority. The hydrodynamic modeling portion was not completed and remains a work item. To date, only one of the stream reaches has been completed in Program River2D. Alignment of fish sampling enclosures to River2D model outputs for this reach will be attempted, hopefully setting a procedure that can be replicated by student workers.

**Personnel status:** One senior personnel continues to work on the project, the project CO-PI has left the University of Connecticut and is less involved at present. This departure has left the PI without needed expertise close at hand. The research assistant that lead the biotic sampling during summer 2006 ended employment after six months as planned and is in now enrolled in graduate school at Tennessee Technological University studying a crayfish species of conservation concern. A PhD student in Geopgraphy/fluvial geomorphology had taken up work on the hydrodynamic modeling but did not complete it. New personnel will be needed to complete this portion of the project. A crew member from the field crew of summer 2006 worked on the macroinvertebrate sorting and analyses as an indepent study project during the fall 2007 and spring 2008 semester. In total to date, nine different students have participated in project-related data collection activities.

![Figure 3. Principal components analyses of fish assemblage data collected in 2006](image)
References


Development of a new generation of sensitive, fluorescence-based nitrate sensors for use in soil and water

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Publication

Development of a new generation of sensitive, fluorescence-based nitrate sensors for use in soil and water
Title: Development of a new generation of sensitive fluorescence-based nitrate sensors for use in soil and water

Statement of regional or state water problem:
Throughout the world, eutrophication of tributaries, rivers, estuaries, and coastal marine ecosystems by point and non-point sources (e.g. industry, sewage, development, atmospheric deposition and agriculture) is changing these ecosystems' biogeochemical function, ecology, and the human institutions dependent on them [1, 2]. Roughly one-third of the nitrogen (N) reaching Long Island Sound (LIS) is derived from non-point sources, and these non-point sources, and the sinks, transport and processing of N in pathways leading to LIS, are not well understood. Integrating data from 28 water monitoring stations (23 in CT) with land-use/land-cover information, population density, runoff volumes, and other landscape characters, Mullaney et al. (2002) developed a simple linear regression model capable of predicting N-loads and yields in streams as a function of watershed characteristics [3]. This model was used to estimate N-loading in unmonitored watersheds, but unexplained discrepancies were found that indicated unknown but important system drivers were affecting N-loading in both agricultural and forested landscapes [3]. In particular for the current effort, researchers noted that the type of forest cover (e.g. percent deciduous tree cover) significantly affects N-loading [3], suggesting either that the dominant tree types themselves [4], and/or perhaps edaphic factors correlated with those forest communities [5], strongly affect N-yield from forested areas. Recently published data suggest that dominant northeastern forest deciduous and evergreen species are associated with distinct rates of N-cycling and N-retention in the soils supporting them [4, 6]; these distinct N-cycling rates could lead to distinct N-load "signatures" in watersheds that correlate with forest cover.

Ultimately, we would like to explore how patterns of N-cycling, and dynamics of various dissolved N pools, correlate with the patterns and growth of diverse New England forests, but current monitoring methods are inadequate. Though current ecosystems ecological techniques for quantifying net and gross mineralization and nitrification, as well as microbial immobilization, of nitrogen have certainly led to greater understanding of patterns in and mechanisms underlying N-cycling in forested systems, those techniques invariably require destructive harvest of soil prior to assay [7]. Unfortunately, digging up the belowground system under study necessarily leads to severing plant roots that contribute carbon to soil, breaking hyphae of mycorrhizal and saprotrophic fungi, mixing up soil layers, and breaking up soil aggregates that otherwise can have cores hypoxic enough to support denitrification. Ecosystems ecology sorely needs a suite of miniature sensors capable of being deployed to continuously monitor dissolved nitrogen species in soils. Because soil processes are notoriously heterogeneous, ideal would be development of an inexpensive and sensitive enough design to support deployment of a suite of such sensors in multiple locations across a watershed so that networked, continuous pool data could be gathered across the landscape. Ecosystems ecologists have long used stream water concentrations of ions as an integrated measure of terrestrial system output (for example demonstrating that immobilization of otherwise mobile essential nutrients in new aggrading forest biomass after logging leads to dramatic and seasonal decreases in nitrate concentrations in streamwater [8]). But the N processing on the terrestrial landscape itself has been studied destructively, not continuously, and often not in situ.

Ecosystems scientists are not alone in needing improved monitoring tools; land managers and environmental engineers also seek sensors that can be deployed in order to detect plumes of contaminants, including nitrate, moving through groundwater. Development of small nitrate sensors is already underway in that context, e.g. at UCLA (see the Center for Embedded Networked Sensing focus on contaminants and terrestrial ecosystems [9]). However, the concentrations of nitrate in a contaminated plume are much higher than background concentrations in forested systems. McDowell showed that nitrate concentrations in soil solution (extracted using zero tension lysimeters, and analyzed in the lab) were between 0 and 1 mg L\(^{-1}\) over a time span of ten years in unmanipulated hardwood and pine stands at Harvard Forest [10]. In contrast, in plots experiencing chronic high N deposition (15 g N m\(^{-2}\) yr\(^{-1}\)) for those same ten years, nitrate concentrations in soil solution ranged between 10 and 28 mg L\(^{-1}\) in pine and hardwood stands. In order to have any hope of monitoring, continuously, shifts in pools of nitrate (and potentially, ultimately, other dissolved N species) in soil solution under particular forest tree species, and in streams draining relatively pristine rather than highly polluted watersheds, very sensitive, miniature sensors are needed. Ideally, such a sensor would be inexpensive
and could be coupled into some of the already established protocols for networking sensors like those being developed at CENS. The first step, however, is how to improve sensitivity of sensors to nitrate in low (background or pristine) concentration in freshwaters and in soil solution, and how to package the sensors in a miniaturized form that is relatively inexpensive.

We aim to develop miniature, “turn-on”, fluorescence sensors for nitrate that, ultimately, can be deployed in sets in soil and in freshwaters to report nitrate concentrations continuously in background and low contamination ranges – e.g. 0-2 mg per liter. Nitrate sensors for deployment in situ are already on the market, for example designed for work in oceans (e.g. UV sensor, Satlantic’s ISUS V2) and streams and groundwater (e.g. Hydrolab nitrate ion selective electrodes [11]). Some are already very sensitive. Satlantic, for example, claims sensitivity of 0.007-28 mg nitrate per liter, +/- 0.028 or 10% of the measurement, whichever is larger. But, the sensor is 2 ft long, 4 inches in diameter, and weighs 11 lbs. New amperometry-based nitrate detectors for use in soil and groundwater are becoming more sensitive, but to date their major focal application has been on highly contaminated nitrate plumes in groundwater [9], though the focus is also shifting to detection in more undisturbed, terrestrial ecosystems. It is important to understand the background N-cycling processes occurring in more pristine environments in order to understand the magnitudes and multiple mechanisms of human impacts on that cycling, yet we lack the tools for in situ monitoring of pools within the heterogeneous N-cycling pool and flux network.

Significance: Statement of results or benefits

Fluorescent sensors are an attractive target for developing a next generation of nitrate detection systems, because fluorescence methodologies are more sensitive, and easier to apply than current technologies. Assistant professor of chemistry Burdette specializes in the chemical synthesis and the principles of photochemistry relevant to sensor construction. Funding from CTIWR for 2 years that is earmarked to support work on developing a fluorescence-based nitrate sensor, and would provide the necessary seed money to initiate the molecular design of a sensing system. Cardon can guide the preliminary tests of sensitivity in real samples from the field, and analysis of comparable data from other detection methods (e.g. anion exchange membrane and buried resin bag-estimates, as well as KCl extraction-estimates of nitrate pools in soil [7]). With a proof-of-concept sensor in hand, more funding (e.g. from NSF’s Bioengineering and Environmental Systems program) will be sought to advance the technology beyond molecular design toward the miniaturization and field-readiness of continuous sensing systems. Because Cardon serves on the national SAMSI program steering committee for development of mathematical and statistical analysis of sensor network data [12], she already has the necessary contacts to help bring the established technology rapidly to an interested community nationwide. Cardon has already collaborated with John Mullaney at USGS and Paul Stacey at DEP in CT writing grant proposals (to NSF) to further explore nitrogen processing in Connecticut’s watersheds and Long Island Sound. The links from the sensor development proposed here to CT government agencies thus promises to be a natural progression.

Nature, scope, and objectives of the project

**Fluorescent Sensors (Fig. 1).** Fluorescent sensors have been vital in identifying the cellular functions of metal ions [13], as well as the impact of environmental contaminants like mercury [14] and polychlorinated biphenyls [15]. With appropriate molecular design, fluorescent sensors are capable of making sensitive measurements using signals that are easy to monitor [16]. Since these chemical tools are typically constructed using modular approaches, simple structural modifications can be made to adapt the sensor for a variety of different applications and circumstances. Analyte concentrations from sub-pM (equivalent of 0.1 μg/L of nitrate) to saturated solutions can be accurately measured. In addition to these advantages, fluorescent sensors
are particularly amenable for monitoring environmental analytes because the imaging reagents and instrumental techniques are non-evasive and simple to employ. One distinct improvement over conventional techniques for measuring nitrate concentrations is that sensors are typically inexpensive and can be designed to be either disposable or reusable. As a result, an array of many individual sensors can be distributed easily over a large area and monitored by one research worker using an inexpensive, portable fluorescence spectrometer. While methodologies for constructing some types of fluorescent sensors are straightforward, designing useful sensors for anions presents a significant challenge. Although fluorescent anion sensors exist, very few systems have been reported for nitrate [17].

**Nitrate chemistry**. The most challenging obstacle to overcome when constructing a nitrate sensor is finding a receptor to bind what is essentially a non-coordinating anion (Fig. 2). Nitrate is a weak base that does not form covalent bonds with metal cations or protons readily, a behavior that is consistent with it being the conjugate base of a strong acid (nitric acid). In the majority of nitrate complexes characterized crystallographically to date, the nitrate group is located several angstroms away from other atoms, hence the nomenclature “non-coordinating” [18]. Unlike metal cations that can form strong covalent bonds with receptors containing electron-donating atoms like oxygen or nitrogen, anion receptors usually rely on noncovalent interactions like hydrogen bonding or electrostatic interactions for chelation [19]. Noncovalent interactions are weak forces, so it is counterintuitive that a receptor using these interactions can bind an analyte tightly; however, if a receptor takes advantage of several noncovalent interactions simultaneously, a reasonably high affinity interaction can be established.

Another challenge in anion receptor design is the ability to discriminate between other anions. In particular for nitrate found in the environment, anions like chloride (Cl\(^-\)), sulfate (SO\(_4^{2-}\)), and phosphate (PO\(_4^{3-}\)) could interfere with measurements of nitrate concentration if the receptor lacks selectivity. In order to enhance selectivity for nitrate, the receptor can take advantage of the coordination number and charge density. Nitrate is a trigonal planar anion, as opposed to primary oxyanions competitors like PO\(_4^{3-}\) and SO\(_4^{2-}\) (tetrahedral), and anions like hydroxide (HO\(^-\)) and halides (F\(^-\), Cl\(^-\), Br\(^-\), I\(^-\)) with simple geometrical shapes. Nitrate is monoanionic, with the charge distributed evenly over the 3 oxygen atoms, making them the primary targets for noncovalent interactions with receptors. The monoanionic, trigonal planar structure of nitrate is an uncommon structural motif for anions found in soil and water. Therefore, receptors that can only accommodate a trigonal anionic guest will provide the desired binding selectivity.

**Dendrimers**. Dendrimers are globular polymers frequently prepared using conventional organic synthetic methodologies (Fig. 3). When convergent synthetic methods are employed [20], dendrimers have uniform size, shape and molecular weight, a property reminiscent of enzyme structures [21, 22]. Because of their unique properties, dendrimers are attractive targets for a variety of applications in catalysis [23], medicine...
Several properties of dendrimers make them attractive scaffolds for environmental nitrate sensors. Dendrimers can be prepared with robust chemical linkages that will resist degradation by microorganisms and variations in acidity/basicity in soil and water. Dendrimers also provide encapsulation, and hence protection, for the nitrate receptors and fluorophores that are susceptible to decomposition reactions under the conditions the sensors will be deployed. Most importantly, however, dendrimers can act as “molecule concentrators” (Fig. 4) [26]. When mobility of an analyte like nitrate is lower (like in soil before reaching water), the ability of the dendrimer to concentrate a substrate will amplify the resulting fluorescent signal. The ability of a dendrimer to act as a concentrator, as well as many other physical properties, is dictated by its chemical structure. Dendrimers have three important structural components, the core, the branching groups (polymer repeat units) and the peripheral groups, that can be varied to tune the properties of the resulting macromolecule. As shown in Figure 4, a dendrimer with a hydrophobic periphery and a polar interior will be predisposed to concentrate a charged molecule like nitrate from nonaqueous sources.

Specific Aims

1. Construct nitrate receptors for incorporation into dendritic fluorescent sensors
2. Verify the ability of dendrimers to concentrate nitrate anions
3. Investigate the strategy of using accumulation of anionic charge inside a dendrimer to modulate the emission intensity of polarity sensitive fluorophores
4. Investigate the viability of displacing a negatively charge fluorescence quencher at the core of a fluorescent dendrimer as a detection strategy
5. Investigate the strategy of using charge-induced swelling and contracting of dendrimers to induce fluorescence resonance energy transfer
6. Demonstrate proof-of-concept nitrate sensing with dendrimers in prepared solutions and environmental water samples
7. Devise methodology to attach/adsorb dendritic sensors onto glass surfaces for nitrate sensing in soil samples

Methodology

General sensor design strategy: dendrimer structure and nitrate receptors. The majority of the existing sensors for anions (e.g. F⁻, Cl⁻, Br⁻, PO₄³⁻, CO₃²⁻) rely on either photoinduced electron-transfer (PET), which requires the formation of covalent bonds with the receptor, or electronic energy transfer (EET), a “turn-off” mechanism which requires an analyte with an electronic structure that triggers fluorescence quenching, as the signaling mechanism [17]. Neither of these common strategies is applicative to the disparate requirements of sensing nitrate. An alternative approach to anion sensing is to couple an accumulation of negative charge with a change in the fluorescence intensity. In aqueous solution, nitrate can freely flow into the dendrimer, and be trapped by the receptors; however, in soil nitrate may be less mobile with respect to entering the dendrimer. In order to concentrate anions, dendritic molecules will be utilized as concentrators. As a consequence of dendrimers possessing hydrophobic peripheries and polar cores, a concentration gradient is established between the interior of the macromolecule and the exterior that provides the driving force to amass nitrate. All three sensor strategies described below will take advantage of
the concentrator effect to sequester nitrate in soil. For sensing in water, the hydrophobic peripheral groups will be substituted for with water-soluble groups like short polyethylene glycol (PEG). In addition to concentrator effects, the interior of the dendrimer will be functionalized with molecules capable of binding nitrate to provide anion selectivity and trapping. Several receptors have successfully been applied to nitrate binding (Fig. 5). Both cryptate [27] and “tweezer” type ligands [28] possess nitrate selectivity, because of the common feature that the binding cavity orients hydrogen-bonding interactions in a trigonal planar coordination sphere. These molecules will be the primary candidates for incorporation into the sensors in this initial phase of the research project. Design of new and improved nitrate receptors will not be a major component of CTIWR funded research; however, future proposals and projects will address any limitations of these systems.

Displacement of a quenching anion by nitrate as a sensing strategy. Although nitrate typically is incapable of quenching fluorescence, large anions (e.g. Br\(^-\), I\(^-\)) quench fluorescence through enhancement of spin orbit coupling (SOC) [29] and electron deficient anions (e.g. 4-nitrobenzene-sulfonate) through SOC [30] or EET [17]. A simple proof-of-principle sensor for this strategy can be constructed with a dendrimer functionalized with ammonium iodide groups and fluorophores. Diffusion of nitrate into the interior will displace the quenching anions restoring fluorescence (Fig 6).

**Principle Findings: Progress Report**

**General progress.** Our work has focused on proof-of-concept research that is focused on two main areas: 1) synthesis of water soluble dendrimers; and 2) synthesis and characterization of sensors containing an anion receptor, a fluorophore and dendrimer mimetic substituents. We have enlisted an undergraduate researcher to continue work this summer. Future progress will be dependent on finding new personnel and additional mechanisms of financial support.

**Dendrimers and Water Soluble Dendrimer synthesis.** During our first year we synthesize poly(benzyl ether) dendrimers, and to date we have prepared G\(_1\)-G\(_3\) dendrimers with

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*Figure 6. Mechanism of signaling action with quenching anions. The presence of iodide anions quenches the emission of the coumarin fluorophore (center), when nitrate binds to the receptors, the iodide will be expelled from the dendrimer restoring the emission.*

*Figure 7. Dendrimers prepared to date*

*Figure 8. G2 water soluble dendrimer. G1 and G3 versions have also been prepared for incorporation into sensors.*
benzyl groups as well as alkyl chains on the periphery (Fig. 7). These components of the model nitrate sensor are available for assembly of the dendritic nitrate sensors proposed originally. We have expanded our efforts in anticipation of constructing sensors for deployment in aqueous solution. Shown in Figure 8 is a water soluble benzyl ether dendron with a naphthalene group at the focal point. The poly(ethylene glycol) units will impart water solubility to future sensors and the naphthalene group is an emissive species that will provide the sensor readout.

**Nitrato receptor synthesis.** As we suggested in our original proposal, our 1st generation of nitrate sensors will utilize known nitrate receptors that we will modified to act as fluorescence switches or to contain synthetic handles for attachment to macromolecules. Based on literature precedence, we have modified the structure of a biphenyl-based nitrate receptor to contain a binaphthol scaffold (Fig. 9). We accessed the binaphthol ligand through a multi-step synthesis that is amenable to making a variety of related derivatives or making additional structural modifications. Unlike biphenyl, binaphthol is inherently fluorescent, but we have not observed any emission changes when it binds nitrate; however, this may still be a useful sensor component by incorporating components of the anion sensing mechanism described below.

**Investigation of sensing mechanisms.** One of the key preliminary studies we have undertaken is an attempt to determine a mechanism that will allow changes in nitrate concentration to increase sensor emission. As described in the proposal, nitrate in a weakly coordinating anion, and therefore many common sensing mechanisms are not appropriate for our purposes. We successfully tested the hypothesis that nitrate can displace a quenching group that is in proximity to a fluorophore by preparing an anthracene derivatives containing two tetra-alkyl ammonium iodides (Fig. 10). The lipophilic alkyl groups to give the resulting sensor solubility in nonpolar solvents like hexanes or toluene. In these nonpolar solvents, the iodide anions form a close ion pair with the...
ammonium cation, and the close proximity of the iodide quenches the emission of the anthracene by creating spin-orbit coupling quenching pathways. Subsequent displacement of the quenching iodides by with nitrate restores anthracene fluorescence (Figure 11). The formation of insoluble silver iodide drives the formation of the ammonium nitrate species. we will begin to integrate our sensing strategy with the receptor and dendrimer components. An sample target we are working toward is shown in Figure 12.

Figure 12. Modular representative of nitrate sensors under preparation. The sensor incorporates dendrimer (blue), anion receptor (red) and a fluorophore (green).
References


The Geochemical Record of Cultural Eutrophication in Sediments of Beseck Lake and Lake Waramaug, Connecticut: Implications for Nutrient Cycling and Remediation Efforts

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Publication
The Geochemical Record of Cultural Eutrophication in Sediments of Beseck Lake and Lake Waramaug, Connecticut: Implications for Nutrient Cycling and Remediation Efforts

Proposal IDs: Ku2007_104B_R, Ku20082009_104B_R
Principle Investigator: Timothy Ku, Wesleyan University

Problem and Research Objectives

Anthropogenic activities have dramatically altered the biogeochemical cycles of carbon, sulfur, nitrogen, and phosphorous in nearly every major aquatic ecosystem on Earth (Smith, 2003). Cultural eutrophication is the process whereby human activity increases the amount of nutrients, primarily nitrogen and phosphorous, entering an aquatic ecosystem causing excessive biological growth. The accelerated production of autochthonous organic matter results in anoxic conditions within the water column, thereby changing the community structure of aquatic ecosystems and degrading the recreational and retail value of the surrounding land. Eutrophication is a widespread environmental problem as it accounts for ~50% of impaired lake area and 60% of impaired river reaches in the U.S. (U.S. EPA, 1996). In Connecticut, prior to the mid-1800s the land was mostly forested, but increases in agriculture, urban, and residential land areas contributed to the eutrophication of several Connecticut lakes by the 1930s (Deevey, 1940; Bell, 1985). Progressive eutrophication associated with land-use changes continued in many Connecticut lakes as average Secchi disk depths decreased by 1.2m and total phosphorous concentrations doubled from the late 1930s to the early 1990s (Siver et al., 1996). During approximately the same time, mean estimated total phosphorous (eTP) and mean estimated total nitrogen (eTN) concentrations increased from 15 and 374 µg/L to 25 and 450 µg/L, respectively (Field et al., 1996). These results, together with biological-based paleolimnology studies, clearly demonstrate that anthropogenic activities have accelerated the eutrophication process in many Connecticut lakes (Siver et al., 1999).

To reverse or decelerate cultural eutrophication, many regulatory agencies have implemented stringent laws intended to lower the delivery rate of nutrients into impacted water bodies such as the Chesapeake Bay, Lake Erie, and Lake Baldeggersee (Switzerland) (Lotter, 1998; Boesch, 2002). In Connecticut, the Long Island Sound study aims to reduce nutrient inputs delivered to Long Island Sound, but restoration or preservation of inland lakes is usually the responsibility of local governing agencies working in conjunction with the Connecticut Department of Environmental Protection (NYSDEC and CTDEP, 2000). This study focuses on two eutrophic Connecticut lakes that have been the focus of major remediation efforts, Lake Waramaug and Beseck Lake. Lake Waramaug experienced significant eutrophication from the 1950s through the 1980s and two hypolimnetic withdrawal systems were installed in 1983 to contain the phosphorous in the bottom waters of the lake. Since 1983, additional remediation efforts have included the installation of two in-lake layer aeration systems, the passing of new zoning regulations to limit soil and water runoff, and the stocking and seeding of fish and zooplankton to improve water quality (http://www.lakewaramaug.org). The Lake Waramaug Task Force (LWTF) is a non-profit organization of volunteers and scientists and together with Ecosystem Consulting Services, Inc. has continuously monitored the lake since 1977. During this time, the lake water clarity has improved and epilimnion phosphorous concentrations have declined (ECS data, pers. comm.). Beseeck Lake is a manmade impoundment created by a dam in
the mid 1800s and has experienced episodic eutrophic conditions from the 1970s to the 1990s, in part due to the addition of nutrients from failing septic systems (Canavan and Siver, 1995; Cinotti, 1997; Jacobs and O’Donnell, 2002). To decrease the flux of nutrients entering the lake, surrounding residences were converted from septic systems to a city sewer system. This transition was completed in 2002 and the Lake Beseck Association now helps maintain and monitor the lake water quality (R. Boyton, pers. comm.).

While these efforts to decelerate the eutrophication process have yielded positive results, future remediation policies must set realistic goals of water quality (chemical composition and biologic activity). By using historical data, time series data, or reference region data, regulatory agencies can determine pristine water quality conditions that are absent of the effects of human activity (Smith, 2003). Sediment cores collected from Beseck Lake and Lake Waramaug record the pre-anthropogenic lake conditions and the onset and remediation of cultural eutrophication. This project examines the history of these two lakes, which will help guide future remediation efforts in Beseck Lake and Lake Waramaug as well as in other worldwide lakes experiencing similar eutrophication problems.

**Methodology**

The three main objectives of this study are 1) determine the sedimentation rates of organic C, organic N, and detrital minerals, 2) determine the source of organic matter and detrital minerals, and 3) determine the paleoredox history of these lakes. Sediment push cores and freeze cores were collected using a pontoon boat. Linear sedimentation rates (LSR, cm/yr) and mass accumulation rates (MAR, g/cm²/yr) were determined by \(^{210}\)Pb, \(^{137}\)Cs, and Hg and Pb methods (Appleby and Oldfield, 1992; Siver and Wozniak, 2001; Callender, 2004; Fitzgerald and Lambourg, 2004; Varekamp et al., 2005). Organic C and N concentrations were analyzed with an elemental analyzer. Major, minor, and trace element compositions were determined by digesting sediments in a HCl/ HNO₃/ HF/ HClO₄ solution followed by ICP and ICP-MS analyses. \(\delta^{13}\)C and \(\delta^{15}\)N organic matter measurements were performed at the Stable Isotope facility at Indiana University. Paleoredox indicators (DOP, \(\delta^{34}\)S_pyrrole, and pyrite framboid size distributions) were analyzed using Fe-S methods and sediment phosphorus species (labile P, Al-P, organic P, and Fe-P) were determined by a sequential sediment extraction method (Canfield et al., 1986; Raiswell et al., 1994; Wilkin et al., 1996; 1997).

**Principal Findings and Significance**

Eight and seven sediment cores were collected from Lake Waramaug and Beseck Lake, respectively. Three sediment cores have been dated and represent 200 to 400 years of lake history. In Lake Waramaug, the Hg and Pb sediment concentrations increase at ~1900 A.D. due to fossil fuel use related to the Industrial Revolution and peak concentrations are found between 1950-1970 A.D. Compared to times before ~1900 A.D., Lake Waramaug experienced a period of higher C/N ratios shortly after 1900 A.D. that indicates a greater proportion of allochthonous organic matter being delivered from the surrounding watershed. This could be related to increased forest clearing, a major storm event, or a period of increased rainfall. The organic C, C/N, and \(\delta^{15}\)N values (background 0.4‰) all indicate increasing cultural eutrophication throughout the 1900s and the highest organic matter \(\delta^{15}\)N value of +3.1‰ occurring in the 1970s-1980s. The \(\delta^{15}\)N values decrease from this peak time to values of +1.9‰ today and this is likely related to the remediation efforts of the Lake Waramaug Task Force, which significantly
decreased the external nutrient inputs and implemented in-lake restoration solutions since the 1970s-1980s. This finding is significant because this represents one of the few cases where remediation results are documented by lake sediments. Sediment iron-sulfur paleoredox indicators show high spatial and temporal variability demonstrating that Fe-S-P cycling has been greatly altered by human pollution and remediation activities. In general, our data show that the oxic/anoxic interface has fluctuated significantly over the last ~70 years, which has caused the fraction of Fe-bound phosphorus to decrease in recent times. Additionally, sulfuric acid from acid rain sources appears to have increased the ratio of pyrite Fe to reactive Fe, which would further decrease the amount of reactive iron available to bind phosphorus. Due to the high variability of Fe-S-P chemistries between sediment cores, we have had to 210Pb-date more cores than anticipated to firmly establish sediment chronologies. This data is currently being collected and we anticipate that all data will be collected during the summer of 2009 and the first manuscript focusing on Lake Waramaug will be submitted for publication in August 2009.

In Beseck Lake, the sediments document the time from prior to the mid-1800s, when the lake water was raised by damming the outflow, to the last few years. Higher C/N ratios mark the older swamp sediments and increased cultural eutrophication results in greater concentrations of organic C, lower C/N ratios, and higher δ15N values. Unlike Lake Waramaug, a decrease in δ15N values is not observed, however, that signal may be lost due to moderate bioturbation of the bottom sediments. The sediment Fe-S-P chemistries do not show significant changes over time, but rather show clear correlations with current water column heights and average overlying dissolved oxygen concentrations. In shallow, oxic portions of the lake, there is low total phosphorus and most of the phosphorus is found in non-Fe phases. However, in the deeper, anoxic portions of the lake, there are higher total phosphorus concentrations with iron-phases comprising the most important P-binding phase. These results highlight the importance of iron and sulfur cycling to the available phosphorus budget and demonstrate that the dominant P-bearing phase may shift due to human activities.

Our findings will help the Lake Waramaug Task Force and Beseck Lake Association with future remediation decisions and provide the scientific community with a rare opportunity to compare recent sediment geochemistry with long-term, remediation efforts. We expect that future researchers will use the techniques and results from this study to examine other eutrophic water bodies, thereby making Beseck Lake and Lake Waramaug the model examples for this type of work.

References


Rapid and Sensitive Detection of Total Coliforms and E. coli Using SWNT Membrane

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Publication

Rapid and Sensitive Detection of Total Coliforms and *E. coli* Using SWNT Membrane

By Yu Lei

Research Progress

In the proposed research, we will develop amperometric biosensor system, based on the activity of β-D-galactosidase (Total coliforms) and β-D-glucuronidase (*E. coli*). SWNT membrane fabricated on commercial filter membrane will be used as concentrator for target bacteria as well as microbial-immobilized working electrode in amperometric detection. *p*-nitrophenyl-β-D-galactopyranoside (PNPGal) and 8-hydroxyquinoline-β-D-glucuronide (8-HQG) are specifically selected as “electrogenic” substrates for β-D-galactosidase (Total coliforms) and β-D-glucuronidase (*E. coli*), respectively. The corresponding hydrolyzed products, *p*-nitrophenol (PNP) and 8-hydroxyquinoline (8-HQ), will be amperometrically detected at different oxidation potentials in sequence.

Graduate student Liang Su was recruited in Fall 2008 to work on this project. One manuscript titled “Amperometric detection of *E. coli* using 8-hydroxyquinoline-β-D-glucuronide as a specific substrate” is under preparation. Following is the research progress to date.

1. **Hydrodynamic voltammogram for substrates and their enzymatically hydrolyzed products**

PNPGal and 8-HQG are specifically used as substrates for enzymes. β-D-galactosidase (Total coliforms) catalyzes the hydrolysis of PNPGal to generate PNP, while β-D-glucuronidase (*E. coli*) hydrolyzes 8-HQG to release 8-HQ (Fig. 1). Both PNP and 8-HQ are highly electroactive compounds and can be electrooxidized on the electrode surface at different applied potentials. In order to find the optimal applied potentials for the detection of 8-HQ and PNP, hydrodynamic voltammogram was carried out using flow injection analysis (FIA) system. The mobile phase in the FIA system was 0.1 M pH 7 phosphate buffer which was delivered at a constant flow rate of 120 μL/min. The current responses of 8-HQ, PNP, 8-HQG, PNPGal and phosphate buffer at different applied potentials were investigated by injecting 20 μL of 50μM solution of 8-HQ, PNP, 8-HQG, PNPGal, and bare phosphate buffer, respectively. The applied potential was varied manually from +0.3 V to +1 V with a step of 0.1 V. The current response at each potential was recorded. Figure 2 shows a typical hydrodynamic voltammogram for 50 μM PNPGal, 50 μM 8-HQG, 50 μM PNP, 50 μM 8-HQ in phosphate buffer and bare phosphate buffer over +0.3 to +1.0 V potential range at room temperature.
Rapid and Sensitive Detection of Total Coliforms and \textit{E. coli} Using SWNT Membrane

\textit{By Yu Lei}

temperature. Each data point was given as mean ± standard deviation. As expected, there is no response from phosphate buffer over the tested potential range. In addition, no obvious oxidation was observed for 8-HQG and PNPGal (two enzymatic substrates), indicating that the interference from the specifically selected “electrogenic” substrates is negligible. Furthermore, the oxidation of 8-HQ (enzymatic product of 8-HQG by \(\beta\)-D-glucuronidase) starts at +0.4 V, increases sharply up to +0.6 V, and then gradually levels off thereafter, while the oxidation of PNP (enzymatic product of PNPGal by \(\beta\)-D-galactosidase) starts at +0.75 V and increases sharply thereafter. This means that the detection of 8-HQ can be conducted at +0.6 V without interference from PNP oxidation, and the detection of PNP can be performed at a higher applied potential (e.g., +1.0 V) after the deduction of the response from 8-HQ. The hydrodynamic voltammogram result indicated that the two selected “electrogenic” substrates are suitable for the proposed research and make the simultaneously amperometric detection of total coliforms and \textit{E. coli} possible.

2. Preparation of bacterial cultures

\textit{E. coli} XL1 Blue, obtained from the strain collection of our laboratory and used as a model bacterium, is inoculated into Luria broth (LB) medium and incubated overnight on a gyratory incubator shaker at 37 °C and 200 rpm, which allows the growing stationary phase to be reached. Then, bacterial cultures are serially diluted (10-fold steps), and 10 \(\mu\)L aliquots of samples are applied to LB agar plates and incubated for 24 h at 37 °C, for enumeration of colonies. At the same time, the stationary-phase cultures are diluted to different concentration ranging from 1 cfu/mL to \(10^6\) cfu/mL in buffer.

3. Demonstration of amperometric detection of bacteria through the enzymatic activity of \(\beta\)-D-galactosidase and \(\beta\)-D-glucuronidase

We investigated the feasibility of the detection of \textit{E. coli} in spiked water sample based on the enzymatic activity of \(\beta\)-D-galactosidase and \(\beta\)-D-glucuronidase. Our final target is the detection of \textit{E. coli} with a concentration of 1 cfu/mL or even lower. As we proposed to use SWNT membrane (surface area is 12.25 cm\(^2\)) as concentrator, theoretically, if the bacteria concentration is 1 cfu/mL and the filtration rate of water sample through the membrane is 10 L/min, \(2\times10^5\) cfu can be held/immobilized on the SWNT membrane in 20 min. Therefore, as our first demonstration, we use 8-HQG and PNPGal for the detection of \(1\times10^6\) cfu \textit{E. coli}. Figures 3 and 4 show the current response of \(1\times10^6\) cfu \textit{E. coli} incubating with PNPGal and 8-HQG, respectively. As shown in the figures, after we added 8-HQG (Fig. 3) and PNPGal (Fig. 4) to \textit{E. coli} suspension, we can easily distinguish the current response from the controls (\textit{E. coli} without substrate or only substrate) due to the generation of 8-HQ and PNP (the enzymatic products of PNPGal and 8-HQG). This indicated that fast and sensitive detection of \textit{E. coli} using proposed two “electrogenic” substrates highly feasible. The
Rapid and Sensitive Detection of Total Coliforms and \textit{E. coli} Using SWNT Membrane

By Yu Lei

sensitivity will be improved by optimizing the operating conditions.

4. Fabrication of conductive single-walled carbon nanotube membrane for the proposed research

Four mg commercial single-walled carbon nanotubes (SWNTs, 1~2 nm in diameter and 5~30 \( \mu \text{m} \) in length) with >90\% purification were suspended in 20 mL deionized water with 1 wt\% sodium dodecyl sulfate (SDS). The suspension was ultra-sonicated for 15 min and then filtered through 0.45 \( \mu \text{m} \) filter membrane (diameter 4.7 cm) using vacuum pump. The SWNTs were held on the filtration membrane and formed a homogenous and thin SWNT film/network with high porosity. Residual surfactant left in the SWNT film is subsequently washed away with excessive DI water. The prepared membrane was sterilized by ethanol (or autoclave), dried in Level II Biological Safety-Cabinet, and ready for use. The SWNT film shows highly electrical conductivity. An optical image of the as-prepared SWNT film on supporting membrane is presented in Figure 5A. The SWNT film attaches to the supporting membrane tightly and has excellent mechanical properties. Figure 5B shows a typical SEM image of the as-prepared SWNT film. A porous SWNT film consisting of many long SWNT bundles can be seen in the image. It can also be observed that there are many SWNT bundles entangling each other and forming a dense network. The thickness of the SWNT films can be readily controlled, with nanoscale precision, by the SWNT concentration and volume of the suspension filtered. The size of SWNT membrane is ultimately limited only by the dimensions of the filtration membranes.

Future Work

1. Simultaneous concentration and immobilization of target bacteria on SWNT membrane and its amperometric detection

2. Optimization of the amperometric sensor system

3. Application for real water samples obtained from the Department of Public Health, Connecticut. Parallel experiments will be conducted by PI group (proposed amperometric method) and the Microbiology lab (commercial method), Department of Public Health, CT, and the results will be compared.
Optimization of Acidogenic Anaerobic Wastewater Treatment with The Potential for Water Reclamation

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Publication

Research: The research project focused on the optimization of acidogenic anaerobic wastewater treatment, wastewater effluent quality and the bioenergy production from wastewater treatment. Anaerobic treatment has been extensively tested in batch-mode (100 mL) and continuous-mode (2L). The effects of contaminant concentration, pH, and temperature on wastewater treatment and hydrogen production have been elucidated. The correlation between biogas production and liquid fermentation products has been determined. The microbial communities under different operational conditions have been analyzed. In addition, acidogenic wastewater treatment process is also connected with microbial fuel cell (MFCs) to further treat the anaerobic effluent for water reclamation.

The research has provided significant value for the professional development of Mr. Yogesh Sharma. He has presented at several conferences and won the Poster Award in WEFTEC 2008 Annual Conferences. He also submitted three journal papers based on the research project.

Research to be conducted in 2009: Due to the success of batch-mode tests and preliminary results of continuous-mode results, the optimization of continuous-mode systems will be conducted in 2009. The effects of contaminant concentration, pH and temperature on wastewater treatment efficiency, hydrogen production and liquid fermentation pathways will be extensively investigated in the continuous-flow systems, which is similar to the real-world treatment processes. Microbial communities under each operational condition will be analyzed.

Presentation delivered from the project.

Journal paper submitted from the project.
Information Transfer Program Introduction

This year CTIWR did not fund any external information transfer projects. Our Institute's IT activity was funded entirely under the "Water Resources Technology Transfer Initiative" project described below.
Water Resources Technology Transfer Program

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Publication


**Web Site:** Our office maintains the CT IWR web site, which is updated on a quarterly basis (or as needed). It includes information about the WRI program, our institute and its board, a listing of the current year's seminars, a list of sponsored projects and publications, and access to electronic copies of our "Special Reports" series. We also use the web to announce special events and our RFP. We continue to cooperate with the University of Connecticut's digital archives department, which maintains our electronic reports as a part of its "Digital Commons @ University of Connecticut" project.

**Publications:** We will be adding the final reports for our recent DEP projects to our “Special Reports” series that is hosted on the UCONN library’s DIGITAL COMMONS server. These are listed below. In addition, one Masters Thesis was generated by a student funded through CTIWR’s state appropriation.


**Seminar Series.** The CTIWR has begun co-sponsoring the seminar series offered by the Department of Natural Resources Management and engineering, the administrative home for our Institute, instead of holding its own, separate series. Pat Bresnahan serves on the steering committee and actively seeks out speakers with a water interest. Each semester the CTIWR provides financial support to bring in one outside speaker as the “Kennard Water Resources Lecturer.” Dr. William Kennard was the first Director of our Institute, and we honoring his contribution to our program in this way. Copies of the series are attached.

**Conferences.** The Institute co-sponsored or served on the steering committee for a number of conferences:

- April 2009. Water Scarcity and Conflict, Connecticut College. CTIWR provided financial support to cover travel expenses for one speaker. (~$1000).

- March 9, 2009. Connecticut Conference on Natural Resources. Steering Committee: Warner, co-chair, Bresnahan, Member. CTIWR also Contributed $500.

**Service and Liaison Work.** Both the Director and Associate Director actively serve on a number of water-related panels.

- Willimantic River Aquatic Study, UCONN Wellfield Impacts on Streamflow: Glenn Warner is a member of the technical advisory group.
- Groton Drinking Water Quality Management Plan Stakeholder Group - Pat Bresnahan observed a number of the meetings of this community-based water planning effort as an official guest.
- Monitoring the Impact of Invasive Shrub Removal in a Riparian Corridor in Schoolhouse Brook Park, Mansfield, CT. Pat Bresnahan is working as a volunteer on this project, serving mainly as the field data coordinator, and is also contributing a few hours per month of CTIWR time to maintain the project’s web site as a page off of the CTIWR site.
- Governor’s Climate Change Adaptation Subcommittee Workgroups. Glenn Warner is serving on the Agriculture workgroup and Pat Bresnahan is serving on the Infrastructure workgroup.
USGS Summer Intern Program

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Notable Awards and Achievements


2007CT134B: Sediment cores were collected from Lake Waramaug and Beseck Lake. The sediments have been dated using 210Pb, Hg, and Pb chemistries and cover the last 80 to ~400 years of lake history. Sediment analyses of lake productivity (organic matter C, C/N, d15N), nutrient availability (P-speciation), and paleoredox (DOP, d34S) demonstrate that both of these aquatic systems have experienced significant anthropogenic changes, which can, in these cases, be improved through remediation techniques.

2008CT170B: Up to date, 8-hydroxyquinoline glucuronide and p-nitrophenyl- -D-galactopyranoside (and/or p-aminophenyl- -D-galactopyranoside) are specifically selected as the substrate of E. coli and total coliform, respectively, from a pool of available glucuronide and galactopyranoside derivatives. Hydrodynamic voltammograms of the substrates and their corresponding hydrolysis product, 8-hydroxyquinoline and p-nitrophenol (and/or p-aminophenol) were performed to determine the optimal detection potential of the products. After that, a sensitive method for rapid detection of E. coli by flow injection analysis was developed. In addition, SWNT membrane has been fabricated as a filter.