Water Resources Center
Annual Technical Report
FY 2010

Introduction

Delaware Water Resources Center

June 1, 2011

The Delaware Water Resources Center receives an annual Federal matching grant as authorized by section 104 of the Water Resources Research Act of 1984 (Public Law 98-242) as amended by Public Law 101-397, Public Law 104-147, and Public Law 106-374. The U.S. Geological Survey (USGS), Department of the Interior, administers the provisions of the Act. This annual evaluation report describes, in the format prescribed by the USGS, the research, training, and information transfer activities supported by the section 104 grants and required matching funds during fiscal year 2010.

Understanding the nature of the water quality and water supply problems faced in Delaware, historically and today, requires knowledge of the physiographic nature of the state, its climate, and major land uses. Geologically, Delaware is comprised of the Piedmont and Atlantic Coastal Plain Provinces. Only the northernmost 6% of the state is within the Piedmont, a region created of very old igneous and metamorphic rock. Soils range from well-drained, highly productive silt loams in the Piedmont to well– and excessively well-drained sandy loams and loamy sands in the Coastal Plain. Significant areas of poorly drained soils are also present, particularly in southeastern Delaware. Erosion and surface runoff are the main concerns in the Piedmont, while leaching of contaminants to shallow ground waters is the main water quality problem in the Coastal Plain. Average annual rainfall is plentiful (45 inches/year) and rather constant, averaging 3 to 4 inches/month in winter and spring and 4 to 5 inches/month in summer. Precipitation typically exceeds evapotranspiration by 12 to 18 inches/year, providing 10 to 12 inches/year of ground water infiltration.

Surface water is the main water supply source in the Piedmont, although the Cockeysville Formation is an important local aquifer of fractured marble and dolomite. This province is dominated by the Christina River Basin, fed by rivers that first flow extensively through Pennsylvania and Maryland. Water quality of the White Clay and Red Clay Creeks and Brandywine River is strongly affected by land use and point sources of pollution in neighboring states. Those rivers flow into the Christina River which, in turn, flows into the Delaware River.

Ground water is the major water supply source for the Atlantic Coastal Plain, a province of southeastwardly thickening unconsolidated and semi-consolidated sediments over crystalline basement rock. A primary aquifer in this province for water supply, stream base flow, and confined aquifer recharge is the unconfined Columbia aquifer. In a southwardly expanding wedge, the western portion of this area flows to the Chesapeake Bay through headwaters of the rivers and creeks of the Delmarva Peninsula's eastern shore. The mideast section of the province flows to the Delaware Estuary, fed by the watersheds of 15 creek and river systems. The southwest portion of the state flows into the Inland Bays of Delaware and Maryland and the Atlantic Ocean.

According to the Delaware Office of State Planning Coordination's 2007 Land Use/Land Cover data set, the major land use in Delaware is agriculture (526,070 acres; 41% of the 1.28 million acres in the state), which is dominated by a large, geographically concentrated poultry industry. Other main land uses are urban (19%), wetlands (19%), forests (15%), open water (4%), and barren land (1%). Delaware has 2509 miles of streams and rivers, 2954 acres of lakes/reservoirs/ponds, 841 square miles of estuarine waters, and 25 miles of ocean coastline. Approximately 2/3 of the state's wetlands are freshwater, and 1/3 is tidal.

Protection of the quality and quantity of the state's surface waters and aquifers is a major concern to all agencies and individuals responsible for water resource management in Delaware. Ground water protection is particularly important given the increasing reliance on this resource for drinking water. In general, the key

priority water resource issues today are (not prioritized): (1) enhanced management and control of stormwater runoff, erosion and sediment; (2) improved understanding of sources, transport, fate, and remediation of toxic organics and trace elements; (3) comprehensive management of agricultural nutrients and sediment; (4) identifying sources of pathogenic organisms and preventing human health impacts; (5) increased understanding of the response of aquatic systems to pollutants; (6) identification and protection of wellheads and aquifer recharge areas; (7) better management of water supply and demand and development of a systematic means to deal with droughts and floods; (8) treatment and disposal of on-site sewage; (9) protection and restoration of wetlands; (10) prevention of saltwater intrusion to potable water supplies; and (11) protection of functioning riparian areas.

The Water Resource Problems of Delaware

Surface Water Quality

Point Sources: Delaware has a number of serious, documented surface water quality problems. Many can be traced back to point source pollution problems in past decades; others reflect ongoing anthropogenic activities that degrade surface water quality. Water quality is a major state environmental priority and improvements have occurred, particularly since the 1970s, due to the use of state and federal regulatory and funding means to address "end-of-pipe" point sources of surface water pollution. Much of this improvement was due to aggressive use of federal funding, available in the late 1970s and early 1980s under the Clean Water Act, combined with local funding, to expand and improve municipal wastewater treatment systems.

The National Pollution Discharge and Elimination System (NPDES) Program in Delaware has reduced the number of individual "point source" permits to discharge wastewater from over 200 in the 1970s to 50 as of 2011. Of those, nine are all or almost all stormwater, and six sites have no activity or greatly reduced activity. NPDES permitting programs have been expanded to address pollution in stormwater runoff from concentrated animal feeding operations ("CAFOs," 350 permittees), construction (2238 permittees as of April 2009), and ongoing industrial activities (378 permittees). Current initiatives include implementation of "Total Maximum Daily Load"(TMDL) requirements, in a long term multi-state effort to reduce PCBs in the Delaware River, and implementation of "Best Technology Available" for cooling water intake structures which draw in tens and hundreds of millions of gallons per day of water from Delaware waters. Major reductions in oxygen demanding materials and toxics in surface waters have been achieved. Future investments in water quality will likely weigh the cost-effectiveness of further reducing point source pollution, versus non-point sources of water quality problems. Currently, the Federal American Recovery and Reinvestment Act and the State Clean Water Revolving Fund are providing funds for infrastructure to reduce point source pollution and other pollution sources.

The major surface water quality problems in Delaware include:

Urbanization: A rapidly expanding urban population is increasing pressures on Delaware's surface waters. Rivers and streams are being affected by elevated temperature and low dissolved oxygen levels that can result from degradation of streambanks and stream channels. In residential and urban areas, increases in impervious surface have resulted in greater and flashier stormwater runoff, leading, in turn, to erosion, sedimentation, shallower water levels and destabilization of stream channels. Biological and habitat quality are also being affected by removal of stream buffers and stream bank "hardening" through use of riprap and concrete.

Drainage: Extensive drainage systems have been installed throughout the state, especially in coastal plain areas. Most were constructed in the 1930s and 1940s by the Civilian Conservation Corps and the Works Progress Administration. At that time, building a drainage ditch system involved channelizing and straightening headwaters of existing natural streams, then constructing ditches out and back from the channelized stream. Upland wetlands were often drained to reduce mosquito populations. A state "tax ditch

program" is re-constructing ditches and in doing so wetlands are protected or augmented and management practices are used to minimize impacts to habitat. The effects on the biological and habitat quality of the waterway once it is stabilized are unknown. Another trend today is the proliferation of public ditch projects instead of tax ditches. Public funding makes the choice by landowners to tax themselves for reconstruction and maintenance of ditches less compelling. Public ditch projects are typically smaller (a few hundred feet) in scope and take place in the upper reaches of streams (typical bottom width is 3 feet) to augment mostly residential and some agricultural drainage. These projects are often carried out by the Conservation Districts. Nothing is known about the impacts to water quality or ecology from such projects. This lack of information may be important since protection of small headwater streams is critical to watershed health. Few streams in Delaware are unaffected by current or historic drainage projects that modify watershed drainage, natural stream channel configuration, buffers, and nutrient transport.

Nutrients: Nutrients are a leading cause of water quality degradation in Delaware. Nutrient effects can be seen especially in lakes, ponds, bays, and estuaries that receive nutrients conveyed by rivers, streams, and ground water. According to the State of Delaware's April 1, 2010 combined 305(b) and 303(d) report, Delaware waters are generally considered to suffer from eutrophication and low dissolved oxygen related to nutrient enrichment. Primary land-based sources of nutrients in Delaware are agricultural practices, septic systems, and urban runoff. About 41% of Delaware's land area is devoted to agricultural activities and 19% to urbanized uses. Delaware's agricultural industry has a strong broiler industry component that heavily influences the state's overall agricultural nutrient balance and has long created nutrient management problems because of the large amount of manure that must be land applied; commercial inorganic fertilizers used by farmers, other land managers and homeowners also contribute nutrients to ground and surface waters. About 70% of Delaware's cash farm income comes from broilers, with annual production ranging from 260 to 280 million broilers, primarily in Sussex County, the largest broiler producing county in the U.S.

Other Problems: Toxics have affected Delaware waters resulting in fish consumption advisories for the Delaware River and Bay, Atlantic coastal waters including the Inland Bays, and twenty smaller waterbodies in 2009. The primary pollutant is polychlorinated biphenyl (PCB). Chlorinated pesticides, dioxins, and mercury have also been identified. Though PCBs have long been banned they are persistent in the environment and are transported from land to waters through runoff to settle in waterbody sediments where they enter the aquatic food chain. New designated uses and surface water quality standards as amended on July 11, 2004 indicate that pathogenic organisms in surface waters have negatively affected shellfish harvesting and caused 86% of Delaware's rivers and streams to not fully support the swimming use; 98% do not fully support the fish and wildlife use. Most waters do not meet standards because of nonpoint source pollution impacts.

Ground Water Quality

The domestic needs of approximately two-thirds of the State's population are met with ground water provided by both public and private wells. Most of the water used for agriculture, Delaware's largest industry, and self-supplied industrial use, is also derived from ground water sources. A shallow water table and high permeability soils make Delaware's ground water vulnerable to pollution. Shallow unconfined aquifers are especially vulnerable, though deeper confined aquifers are susceptible as well because they subcrop beneath and are recharged by unconfined aquifers.

Major ground water quality problems in Delaware today are:

Nutrients: Nitrates from agriculture and septic systems are, by far, the major contaminant in Delaware's ground water. There are also some concerns about dissolved phosphorus transport to surface waters by shallow ground water flow in parts of the state where shallow water tables are interconnected with surface waters by ditches and/or tiles.

Organics: Hydrocarbons have also been found as have pesticides, though not at levels which cause alarm. A major source of hydrocarbons, such as MBTE, is leaking underground storage tanks (USTs) while agricultural activities are the source of pesticides. There are 12,050 regulated underground storage tanks in the State; 9651 have been properly abandoned and 2399 are still in use. Since the 1980s 314,040 releases to ground water have been confirmed and 2800 of those (USTs) have been closed. Over the period 2002-2003, 142 sites had confirmed releases with 30 confirmed ground water releases.

Salt Water Intrusion: Problems with private wells occur sporadically from seasonal salt water intrusion along the Delaware River and the Inland Bays/Atlantic Ocean coastal areas. No major problems have occurred and only one public well in Lewes required abandonment.

Trace Elements: Though not considered a health threat, iron concentrations are a widespread problem in Delaware for cosmetic reasons. Many public water supplies have treatment systems to remove iron. Thirty-four percent of 561 raw ground water samples analyzed by Delaware's Office of Drinking Water in 2002 exceeded the secondary contaminant level standard of 0.3 mg/L. Concerns exist about arsenic in ground waters because of the long-term application of this element in poultry manure to soils overlying shallow drinking water aquifers, the presence of brownfield soils in urban areas that had been used as tanneries or other industries, and the lowered drinking water standard for arsenic.

Wetlands Quality: Studies of nontidal wetlands in the Inland Bays and Nanticoke watershed have recently been conducted. Beyond assessment of trends, primarily rate of loss, overall condition of wetlands and identification of major stressors affecting wetland function were recorded. These reports are found at: http://www.wr.dnrec.delaware.gov/Services/Pages/WatershedAssessment.aspx.

Water Supply: Half of Delaware's population is located in the Piedmont (6% of land area) and uses surface water for drinking water. The other 50% of the population relies on ground water and is spread throughout the remaining 94% of the State. With regard to the amount of water used, ground and surface water are of equal importance; with regard to area served, ground water is overwhelmingly dominant. Capacity concerns are important north of the Christina River due to population concentration and the reliance on surface water. For the rest of the state, the reliance on abundant ground water and a diffuse pattern of development suggest that the supply of potable water is not currently a problem. Recent drought emergencies have brought water supply demand in northern Delaware into conflict with the need to maintain minimum pass-through flows in streams for protection of aquatic resources. Benthic organisms, the foundation of the aquatic food chain, cannot move to avoid dry stream bed conditions. This suggests that not maintaining pass-through flows at all times would be detrimental to stream aquatic life. Required pass-through flows can be high; the need to ensure those flows can result in practices or structures such as reservoirs that are economically inhibitory or may cause as much or greater environmental degradation as occasional dry stream bed periods.

Recent Initiatives Promoting Delaware Water Quality

Water quality standards for surface waters in Delaware, revised and adopted effective July 11, 2004 by the Delaware Department of Natural Resources and Environmental Control (DNREC), include amendments to protect swimmers by making bacteria standards consistent with U.S. Environmental Protection Agency guidance and 2000 federal Beaches Environmental Assessment and Coastal Health (BEACH) Act requirements.

To ensure that Delaware waters meet state, regional, and national water quality requirements and goals, the State has one of the most extensive water quality monitoring networks in the nation. Our water resources in this State are regularly tested for biological and chemical parameters. The results are reported in even years in the State's Watershed Assessment Report (305(b) report). Waters that do not meet water quality standards are listed in the State's 303(d) list. Both of these reports are available at:

http://www.wr.dnrec.delaware.gov/Information/OtherInfo/Pages/WatershedAssessment305band303dReports.aspx. The extensive water quality data have allowed tracking of long term progress made towards improving Delaware's water resources.

Delaware's non-attainment of Clean Water Act standards as described in the 1996 303(d) list was addressed by a federal court order requiring the development of total maximum daily load (TMDL) regulations for nearly the entire state, according to a schedule that concluded in 2010 for nutrients and bacteria. TMDLs establish the maximum amount of pollutants a water body can receive daily without violating water quality standards, allowing the use of these waters for swimming, fishing, and drinking water supplies. TMDLs have been established for nutrients, bacteria, PCBs, and toxics. TMDL analysis documents and regulations can be found at:
http://www.wr.dnrec.delaware.gov/Information/OtherInfo/Pages/WatershedAssessmentTMDLs.aspx.

Additional programs are in place to ensure continued compliance with the court order and to achieve water quality standards. Now that TMDLs are in place, Pollution Control Strategies (PCSs) are being developed to address how, where and when pollutant loads will be reduced to achieve TMDL levels. The PCSs generally offer voluntary and regulatory strategies for urban, suburban and agricultural land uses and are developed through a public process where recommendations are made by Tributary Action Teams (TATs), groups of stakeholders formed with the purpose of addressing water quality concerns.

The first PCS in the State, developed to address the TMDLs in the Inland Bays watershed, has been finalized and can be found at: http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/ib_pcs.htm. PCSs for the Appoquinimink, Broadkill, Christina, Murderkill, Nanticoke, St. Jones, and Upper Chesapeake (Chester and Choptank) watersheds have been drafted and will each go through a public review process in the near future. In the Inland Bays, Nanticoke, Murderkill, and Appoquinimink watersheds, the Tributary Action Team (TAT) process and the development of a draft PCS has taken many years. An expedited process was developed to shorten the PCS development process, which was used in the Christina, St. Jones, Broadkill, Chester, and Choptank watersheds. A Team is currently being developed in the Mispillion and Cedar Creek watersheds and additional teams are expected to be formed in other impacted watersheds over the next several years. To follow progress of the TATs or get more information about them, go to:
http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/.

Other DNREC Water Quality Initiatives Include:

Sediment and Stormwater Management Program: The current Delaware Sediment and Stormwater regulations require management of both stormwater quantity and quality of runoff. The first preference in management of runoff water quality are best management practices that promote recharge of stormwater such as Green Technology BMPs. These include filtering practices, and practices that allow for recharge such as filter strips, biofiltration swales, bioretention, and infiltration facilities. The regulations are currently undergoing revisions to address management of stormwater volume, provide for a watershed approach to stormwater management, and strengthen construction site stormwater management requirements. More information on the Delaware Sediment and Stormwater program is available at:
http://www.swc.dnrec.delaware.gov/Pages/SedimentStormwater.aspx. More information specifically related to the proposed regulation revisions is found at:
http://www.swc.dnrec.delaware.gov/Drainage/Pages/RegRevisions.aspx.

Non-point Source (NPS) Pollution: DNREC continues to reduce non-point source pollution through enhanced coordination of the Division of Soil and Water Conservation Cost Share Programs through the USEPA's NPS Management 319 Program and the National Oceanic and Atmospheric Association's (NOAA) Coastal NPS Management 6217 program along with the Delaware Nutrient Management Commission's (DNMC) program through the Delaware Department of Agriculture (DDA) and other programs. The effort allows DNREC to

direct millions of dollars every year toward a comprehensive NPS program to reduce pollutant loads, restore streams and buffers, and install best management practices (BMPs) such as cover crops, nutrient management plans, manure storage structures, manure relocation, and urban best management practices within impaired watersheds. More information on the NPS 319 program is available at: http://www.swc.dnrec.delaware.gov/district/Pages/NPS.aspx, and information on Delaware's Coastal Management Program is available at: http://www.swc.dnrec.delaware.gov/coastal/Pages/CoastalPrograms.aspx.

Stream and Wetland Restoration: Rehabilitating stream corridors by reestablishing natural floodplains and sinuous low-flow channels, stabilizing stream banks, decreasing erosion, improving biological water quality, increasing wildlife habitat, providing buffers along the streams, establishing wetlands, promoting ground water recharge and water storage, controlling invasive plant species and reintroducing native species, trapping and uptake of nutrients are examples of the benefits that result from projects DNREC has implemented to improve the ecological quality and biological diversity in the State's watersheds. Several stream restoration projects completed in northern New Castle County within the past several years along Pike Creek include the Independence School (stream and wetlands), Meadowdale, Three Little Bakers Golf Course (stream and wetlands) as well as Delaware Park along Mill Creek. Wetland restoration projects that feature stormwater being filtered through a wetland before entering a stormwater basin were implemented at Christ the Teacher Catholic School, and the Hindu Temple.

Onsite Wastewater Treatment Systems (Septics): Delaware's "Regulations Governing the Design, Installation and Operation of On-Site Wastewater Treatment and Disposal Systems" were amended in 2002 and 2005 and are currently under review again by the Regulatory Advisory Committee. Legislation was also passed creating a Class H Licensed System Inspector Program which was part of the amended 2005 regulations. Other highlights of the amendments included advance treatment for systems greater than 20,000 gpd, use of effluent filters on all septic tanks, risers on all septic tanks, requirements for all licensees to take 10 hours of continuing education training annually, and for all subdivisions greater than 100 lots to use a community/cluster system with advance treatment. Grant funds have been used in the past few years to implement a septic system pumpout and inspection program, and a holding tank inspection and pumpout program in Sussex County. Both programs have been very successful in identifying failing systems and allowing DNREC to provide assistance to system owners in making repairs or replacements as needed. Resources for the septic inspection and pumpout program only lasted two years as it was a pilot program. However, the holding tank inspection and pumpout program is still operating and has moved statewide with an annual 98% compliance rate. DNREC has also worked with the wastewater community to develop performance standards for nitrogen and phosphorus of onsite wastewater systems which should be incorporated in the revisions to the statewide regulations in the near future. In 2008 the "Regulations Governing the Pollution Control Strategy for the Indian River, Indian River Bay, Rehoboth Bay, and Little Assawoman Bay Watershed" were adopted and in these regulations the performance standards for nitrogen and phosphorus of on-site wastewater systems were adopted as well as the requirement for inspection of septic systems prior to the sale of properties that utilizes septic systems. To view these regulations, go to: http://www.wr.dnrec.delaware.gov/Services/Pages/GroundWaterDischarges.aspx.

Source Water Assessment and Protection: The DNREC Source Water Assessment and Protection Program (SWAPP) provides for the assessment and protection of sources of public drinking water, both surface and ground water. The assessment consists of three critical steps: first, delineation of source water areas; second, identification of existing and potential sources of contamination; and finally, assessment of the susceptibility of the source water area to contamination. The Site Index Database identifies the location and status of both existing and potential sources of contamination within the State. Most potential point sources have been mapped and rated. In 2004, the Source Water Protection Program developed a guidance manual for local governments. This document was updated in 2005. For more information on source water protection, go to: http://www.wr.udel.edu/swaphome/index.html. Delaware SWAPP is a cooperative effort between DNREC,

Delaware Division of Public Health, and the University of Delaware's Water Resources Agency. A citizen's advisory group (CTAC) was formed to assist DNREC in the development and implementation of the program and to ensure public involvement. SWAPP is a multi-phase program that is expected to be completed in the next few years.

Cooperative Efforts: Cooperation among DNREC, residents, other agencies-state and federal, universities, county and municipal governments, conservation districts, and non-governmental organizations (NGOs) helps bring Delaware water goals to fruition. Pollution Control Strategy development and implementation of TMDL regulations is driven by Tributary Action Teams (TATs). The Center for the Inland Bays, University of Delaware Cooperative Extension, the Sea Grant Program at the University of Delaware College of Earth, Ocean, and Environment, University of Delaware Water Resources Agency, Delaware State Cooperative Extension, the Camden-Wyoming Rotary Club, the State of Delaware's Nutrient Management Commission, New Castle, Kent and Sussex County governments, Sierra Club, the county conservation districts, USDA, other DNREC divisions and many others have been vital contributors in the development of PCSs and TATs.

All of the projects implemented in TMDL watersheds to address water quality concerns require a cooperative effort and partnerships to be formed, not just in government interactions, but between members of TATs as well. Finding a solution for cleaner water will require more innovative solutions, greater regulatory control, additional financial resources, and a willingness to make a change by everyone affecting Delaware's watersheds, as we are all part of the problem and we must work together to find a reasonable solution for everyone.

Delaware Water Resources Center: An Overview

The Delaware Water Resources Center (DWRC) has been a part of the University of Delaware since 1965. From 1965 until 1993 the DWRC was located in the University of Delaware’s Research Office. In 1993, the DWRC was formally moved to the College of Agriculture and Natural Resources (CANR) where, since 1997, Dr. Tom Sims, Deputy Dean for Academic Programs and Research, has served as DWRC Director. The DWRC works with all organizations and agencies in Delaware with an interest or responsibility in water resources. We have a 12- to 15-member Advisory Panel representing a wide variety of water resource backgrounds. We regularly cooperate with the Delaware Water Resources Agency, Delaware Geological Survey, Delaware Department of Natural Resources and Environmental Control, the Center for the Inland Bays, the Delaware Nutrient Management Commission, Delaware State University, USDA Natural Resources Conservation Service, Delaware Nature Society, and The Nature Conservancy, to name but a few. The DWRC has always supported a wide range of water resource related research, education, and information transfer programs. We cooperate with many academic departments and units that conduct water-related research at Delaware State University’s Department of Agriculture and Natural Resources and the University of Delaware (UD), including the UD Water Resources Agency in the Institute for Public Administration, the Institute for Soil and Environmental Quality at UD, the UD Departments of Biological Sciences, Bioresources Engineering, Chemistry, Civil and Environmental Engineering, Geography, Geological Sciences, and Plant and Soil Sciences, as well as the UD Colleges of Agriculture and Natural Resources; Arts and Sciences; Engineering; and Earth, Ocean, and Environment. Close communication is maintained between the DWRC and state natural resource agency representatives and water officials to address priority water quality and water quantity concerns in the state. Through efforts such as these, the DWRC has provided key stakeholders a forum for discussion and an opportunity for education regarding water resources.

Section 104 Objectives

The DWRC has defined a three-fold mission to meet the goals of the Water Resources Research Act:

(1) To support research that will provide solutions to Delaware’s priority water problems;

(2) To promote the training and education of future water scientists, engineers, and policymakers; and

(3) To disseminate research results to water managers and the public.

To meet these goals we have focused our efforts into three major areas:

(1) Graduate Fellowship Program: A competitive graduate fellowship program supports graduate fellows on a three-year cycle. Of the two Ph.D. graduate fellows supported during the period of this report, one is in the UD College of Agriculture and Natural Resources and the other is in the UD College of Arts and Sciences. Their research focuses on quantifying carbon amount and quality for transport of contaminants in landscapes and microbiome of the eastern oyster.

(2) Undergraduate Internship Program: We initiated a highly successful undergraduate internship program in 2000. In the first eleven years, over 100 undergraduate internships were made possible via funding from DWRC/USGS, four Colleges within the University of Delaware (UD), UD's Institute of Soil and Environmental Quality, Delaware Geological Survey, DNREC, and the Department of Agriculture and Natural Resources at Delaware State University. DWRC interns work with faculty to conduct research, prepare a written project report, and present their findings at an annual poster conference.

(3) Information Transfer: The DWRC website and newsletters are sources of up-to-date information on DWRC activities and water-related issues of importance to Delaware and the region. Our website provides information on water resources problems, links to water-related organizations, internship and job opportunities in water resources, a calendar of upcoming events, and a Kids Zone for teachers and parents. We also co-sponsor state-wide conferences on water resource topics of current interest.

Delaware Water Resources Center Program Goals and Priorities

1. Institute Director: Dr. J. Thomas Sims, T.A. Baker Professor of Soil and Environmental Chemistry, Deputy Dean, College of Agriculture and Natural Resources, Director, Delaware Water Resources Center, and Institute of Soil and Environmental Quality, 113 Townsend Hall, University of Delaware Newark, DE 19716-2103, Phone: 302-831-2698, FAX: 302-831-6758, email: jtsims@udel.edu

2. Administrative Personnel: Maria Pautler, Program Coordinator, Phone: 302-831-0847, FAX: 302-831-0605, email: mpautler@udel.edu

3. Abstract of Program and Management Overview: The Delaware Water Resources Center (DWRC) research, education and information transfer programs focus on issues of state and regional importance to both water quality and water quantity. Long-term priority areas of the DWRC have included nonpoint source pollution of ground and surface waters, development of ground water supplies, the impact of hydrologic extremes on water supply, and socio-economic factors affecting water supply and water quality. In 2000, the DWRC Advisory Panel identified five specific areas for near-term DWRC research efforts: (1) Agricultural nutrient management and water quality; (2) Basic and applied research on sources, fate, and transport of water pollutants; (3) Quantifying response of aquatic ecosystems to pollutant inputs; (4) Water supply, demand, and conservation, as affected by changing land uses in Delaware and the mid-Atlantic states; and (5) Management and control of stormwater runoff. The FY10 DWRC public water conservation/educational outreach program addressed these issues. DWRC’s research program during the same period addressed these concerns by supporting graduate fellowships in water quality, an undergraduate student internship program, and public information forums including an intern research poster session and a statewide water resources conference.

2010-2011 DWRC Fellowship and Internship Research Program

Two fellowships were funded for the first year in 2010-2011 based on satisfactory progress reporting to the DWRC Advisory Panel:

a) Quantifying the Role of Carbon Amount and Quality for Transport of Contaminants on Our Landscapes: A Watershed Scale Model

Graduate Fellow: Gurbir Dhillon; Advisor: Shreeram Inamdar, Department of Bioresources Engineering, College of Agriculture and Natural Resources, University of Delaware.

b) Microbiome of the Eastern Oyster, *Crassostrea virginica*

Graduate Fellow: Eric Sakowski; Advisor: Eric Wommack, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

Twelve internships were awarded for 2010-2011 based on a review of proposals submitted by potential undergraduate interns and their advisors to the DWRC Advisory Panel:

a) Education and Outreach for the Delaware Wetlands

Undergraduate Intern: Kristin Berry; Advisors: Rebecca Rothweiler, Delaware Department of Natural Resources and Environmental Control and Katy O'Connell, Office of Agricultural Communications, College of Agriculture and Natural Resources, University of Delaware.

b) An Analysis of the Impact of Marcellus Shale Development on Water Resources in Pennsylvania

Undergraduate Intern: Aidan Galasso; Advisor: Janet Johnson, Department of Political Science and International Relations, College of Arts and Sciences, University of Delaware.

c) Use of Recycled Water for Irrigation of Turf and Landscape Plants

Undergraduate Intern: Intern: Stephanie Hahn; Advisor: Anastasia Chirnside, Department of Bioresources Engineering, College of Agriculture and Natural Resources, University of Delaware.

d) The Prevalence of Pathogenic Bacteria in Delmarva Waters from a Virus Point of View

Undergraduate Intern: Mara Hyatt; Advisor: Eric Wommack, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

e) A Watershed Scale Forest Inventory of the Fair Hill Natural Resource Management Area Experimental Watershed in Relation to Precipitation Partitioning.

Undergraduate Intern: Michelle Lepori-Bui; Advisor: Delphis Levia, Department of Geography, College of Arts and Sciences, University of Delaware.

f) The Impacts of Redefining "Navigable Waters" under the Clean Water Act

Undergraduate Intern: Kate Miller; Advisor: Janet Johnson, Department of Political Science and International Relations, College of Arts and Sciences, University of Delaware.

g) Characterization of Submarine Groundwater Discharge Sites in a Coastal Lagoon

Undergraduate Intern: Kevin Myers; Advisor: A. Scott Andres, Delaware Geological Survey.

h) Oyster Restoration Efforts at Delaware Inland Bays: Utilizing RIP-RAP as a Substrate for Oysters

Undergraduate Intern: Jasmine Porter; Advisor: Gulnihal Ozbay, Department of Agriculture and Natural Resources, Delaware State University.

i) Quality of Dissolved Organic Matter in Runoff from Various Watershed Sources

Undergraduate Intern: Suneil Seetharam; Advisor: Shreeram Inamdar, Department of Bioresources Engineering, College of Agriculture and Natural Resources, University of Delaware.

j) The History and Effectiveness of Wetland Mitigation

Undergraduate Intern: Courtney Simmons; Advisor: Steven Hastings, Department of Food and Resource Economics, College of Agriculture and Natural Resources, University of Delaware.

k) Resurfacing Silver Brook Stream and Comparison to Connected Water Bodies

Undergraduate Intern: Hannah Starke; Advisor: Chad Nelson, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

l) Assessment of Changes in Invertebrate Populations Resulting from Wetland Restoration

Undergraduate Intern: Katie Yost; Advisor: Douglas Tallamy, Department of Entomology and Wildlife Ecology, College of Agriculture and Natural Resources, University of Delaware.

Research Program Introduction

None.

Microbiome of the Eastern Oyster, Crassastrea virginica

Basic Information

Title:	Microbiome of the Eastern Oyster, Crassastrea virginica
Project Number:	2010DE171B
Start Date:	9/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Biological Sciences
Focus Category:	Ecology, Non Point Pollution, Conservation
Descriptors:	None
Principal Investigators:	Eric Wommack

Publications

1. Sakowski, E. and E. Wommack, 2011, Exploring the Commercial Microbial Communities of the Eastern Oyster, <i>Crassostrea virginica<i> Progress Report, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 16 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 DWRC Spotlight on Graduate Research, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 7.

Project Title: Exploring the commensal microbial communities of the Eastern Oyster, *Crassostrea virginica*

Investigators: Eric Sakowski, Dr. K. Eric Wommack

Background/ Justification

The American Eastern oyster, *Crassostrea virginica*, plays a vital ecological and economic role throughout its home range. Naturally occurring from the Gulf of St. Lawrence in Canada to the coast of Brazil (Comeau, Pernet et al. 2008), *C. virginica* forms oyster reefs that act as erosional breaks within estuaries and provide protection from predators for many invertebrates and small fish. In addition, *C. virginica* reduces turbidity and improves water quality as it filters water to feed. These oysters are capable of filtering water at a high rate – up to 6.8L h^{-1} (Riisgard 1988) – for a few hours at a time. It is estimated that in colonial times, oysters filtered the entire volume of the Chesapeake Bay (68 trillion liters) in as little as three days. Today, the process takes over a year as the population of oysters in the region has dropped to one percent of historical values.

The decimation of *C. virginica* populations began in the late 19th century as a result of over-harvesting and habitat degradation (Rotschild, Ault et al. 1994). Since the 1950s, two protozoan diseases introduced to the area, *Haplosporidium nelsoni* (the causative agent of the disease MSX) and *Perkinsus marinus* (which causes Dermo), have resulted in oyster mortality and further population decline (Ewart and Ford 1993). Despite these difficulties, the oyster industry remains an important fishery, with an estimated value of over $100 million annually (NOAA NMFS, 2004).

Thus, the study of oyster health and susceptibility to disease is of ecological and economic concern. Understandably, the majority of research regarding oyster microbiology has focused on MSX and Dermo (reviewed in Lafferty, Porter et al. 2004), as well as human pathogens associated with raw shellfish consumption. One area of interest that remains largely unexplored, however, is the impact of commensal microbial communities on oyster ecology and health. Studies of microbial-metazoan relationships in other organisms have demonstrated that commensal microbial communities can influence efficiency of energy extraction from food and may help regulate body weight (Turnbaugh, Ley et al. 2006). Commensal microbial diversity has also been inversely correlated with pathogen colonization in both chickens (Nisbet 2002) and humans (Klepac-Ceraj, Lemon et al. 2010).

Studies of sessile marine invertebrates have shown commensal microbial composition to be host specific, differ from surrounding water and play a role in regulating various metabolic and biogeochemical processes (Raina, Tapiolas et al. 2009; Pfister, Meyer et al. 2010). However, many oyster-related microbial studies have examined the presence/absence of pathogenic bacteria (Lee, Panicker et al. 2003) or phages infecting those bacteria (DePaola, Motes et al. 1998), while knowledge of microbial community structure, dynamics, and impacts on oyster health remain limited. One of the major hurdles to such investigations has been the inability to cultivate >99% of environmental bacteria and viruses (Kennedy, Flemer et al. 2010). Decreasing costs of massive parallel sequencing has now made it

feasible to examine microbial communities at a high resolution across many samples. This project seeks to utilize next-generation sequencing technology to examine oyster-associated commensal microbial community structure and dynamics over time and between healthy and diseased individuals.

Objectives

This project seeks to:

1.) Determine the abundance of bacteria and viruses in oyster extrapallial fluid and water over time
2.) Identify commensal bacterial diversity within extrapallial fluid and surrounding water using molecular-based approaches
3.) Identify viral diversity within extrapallial fluid and surrounding water using molecular-based approaches
4.) Observe differences in the commensal microbial communities of healthy and MSX or Dermo-infected oysters

Methodology

Oyster cultivation. Oysters were harvested from Lewes, DE and placed in an aquarium in the lab. Oysters were maintained for several months prior to processing of oyster and water samples to allow for the oysters to become accustomed to their surroundings.

Collection of natural samples. Five oysters were harvested each month from the Smithsonian Environmental Research Center (SERC) in Edgewater, MD and transported 20 minutes to Annapolis, MD for processing. Each oyster was rinsed with DI and scrubbed with 70 percent ethanol prior to mantle fluid extraction. A hole was drilled into the posterior end of the oyster at the interface between valves. Mantle fluid was extracted using a 5mL syringe. Samples were placed on ice and transported back to Newark, DE for further processing. A 10L water sample was collected at the same site and time as the oysters. The sample was placed in a cooler filled with water from the site to maintain temperature for transport back to Newark, DE.

Bacterial and viral counts. A 200µL aliquot of each oyster sample was combined with 37% formalin to a final concentration of 1%, snap-frozen in liquid nitrogen, and stored at -80°C to be used for bacterial and viral counts. Likewise, 4.5mL of the sample water was combined with 37% formalin and frozen for counts. Samples were thawed on ice and combined with 0.22µm-filtered 1x PBS in the following ratios: 10µL extrapallial fluid in 990µL PBS for oyster samples; 70µL water in 930µL PBS for water samples. The solutions were rocked at 30°C for twenty minutes and then vacuum filtered onto a Whatman 0.02µm, 13mm Anodisc filter. Filters were stained with 400µL of 2.5x SYBR Gold in the dark for fifteen minutes prior to being mounted onto slides. Slides were placed at -20°C until viewing.

Bacteria and viruses were visualized using epifluorescence microscopy with a 40X oil-immersion objective. Pictures were taken at 15 randomly-selected sites on each filter. Viruses were counted using the iVision software. Bacteria were counted manually. Bacterial and viral abundances were calculated based on the following

equation: Vt = Vc ÷ Fc × At ÷ Af ÷ S, where Vt = viral abundance mL^{-1}, Vc = total number of viruses counted, Fc = total number of fields counted, At = surface area of the filter (μm^2), Af = area of each field (μm^2), and S = volume of sample filtered (mL) (Suttle and Fuhrman 2010).

Bacterial DNA isolation. Oyster samples were combined with 1x PBS buffer at a 1:25 ratio and rocked for 1 hour at 30°C. Samples were then filtered through a Millipore Sterivex 0.22µm filter unit. Approximately 500mL of water was pumped through a Millipore Sterivex 0.22µm filter.

DNA was extracted from each of the filters as follows: 10µL of proteinase-K (20mg/mL) and 20µL of lysozyme (100mg/mL) were combined with 1mL of DNA Extraction Buffer (DEB; 100 mM Tris buffer (pH 8), 100 mM NaEDTA (pH 8), 100mM phosphate buffer (pH 8), 1.5 M NaCl, 1% CTAB) and added to the filter. Filters were incubated at 37°C for 30 minutes and the samples transferred to 2.0mL microcentrifuge tubes. Samples were frozen at -80°C for 15 minutes and thawed at 37°C for 5 minutes three times, followed by incubation in a 37°C water bath for 30 minutes. 100µL of 10% SDS was then added and the sample incubated for 2 hours in a 65°C water bath. The microcentrifuge tubes were then filled to the top with phenol:chloroform:isoamyl alcohol(25:24:1) and centrifuged at 3000rpm for 5 minutes at 4°C. The top layer was transferred to a new microcentrifuge tube and the phenol:chloroform:isoamyl alcohol step repeated. The top layer was transferred to a new tube and combined with 0.6 volumes of room temperature 100% isopropanol. Samples were incubated at room temperature overnight and then centrifuged at 13,000rpm for 30 minutes. The isopropanol and buffer were removed and 1mL of 70% ethanol added. Samples were centrifuged at 13,000rpm for 10 minutes. The ethanol was removed, followed by a second addition of ethanol and centrifugation. The pellet was then allowed to dry and resuspended in 1x TE buffer. Pellets were allowed to dissolve for one hour at 4°C and then stored at -80°C.

16S amplification, barcoding, and sequencing. Forward primer 27F and a reverse primer with a unique barcode were used to amplify ~400bp sections of the 16S rRNA gene. Primers were obtained from the Institute for Genome Sciences. PCR amplification of samples was performed using the following conditions: 95°C for 5 minutes; 33 cycles of 95°C for 30 seconds, 52°C for 30 seconds, 72°C for one minute; 72°C for 7 minutes. PCR reactions were run on a 1.8% agarose gel. Bands were excised using the Qiaquick Gel Extraction kit. Samples were sent to IGS and sequenced using the Roche 454 Genome Sequencer FLX Titanium system. Operational taxonomic unit (OTU) analysis was performed using QIIME.

Results and Discussion

Bacterial and viral abundance. Bacterial and viral abundance were measured from 5 oysters and one 10L water sample once per month. Sample collection began in October 2010 at the Smithsonian Environmental Research Center (SERC) and is still ongoing. At the time of this writing, bacterial and viral abundance has been tracked over six months. Bacterial and viral abundance were variable from month to month, and preliminary analysis of data shows similar patterns between extrapallial fluid and water samples (Figure 1). Although these

data are preliminary and require replicates to determine if statistically significant differences are present, the similarity in shape between oyster and water samples suggests common forces are influencing bacterial and viral abundance in both samples. In each month, viral (Figure 2) and bacterial (Figure 3) abundances were greater in the extrapallial fluid of oysters than the surrounding water, while both samples displayed similar ratios of viruses-to-bacteria (Table 1). On average, oyster samples contained 6.8x as many viruses and 7.1x as many bacteria as the surrounding water; however, replicates need to be measured to determine if these differences are significant. It is interesting to note that the viral-to-bacterial ratio increased in both oyster and water samples in the months of January-March as compared to the previous three months. This occurred in spite of a general decrease in both bacterial and viral abundance over this time, suggesting that loss of bacterial cells may have been occurring at a more rapid rate than loss of viral particles in oyster and water samples.

Bacterial diversity. Initial experiments involving 16S PCR amplification and sequencing were performed on oysters grown in the lab and the aquarium water in which they lived. A total of 5,347 and 5,118 sequences were obtained from the metagenomic libraries isolated from the water and oysters, respectively (Table 2). OTUs were classified using the RDP classifier built into the QIIME software. Analysis of the bacterial community composition indicates that the aquarium water was dominated by α-proteobacteria and flavobacteria, which accounted for 96% of all sequences (Figure 4). Surprisingly, this dominance continued at the family level, as Rhodobacteraceae and Flavobacteraceae combined for 90% of all sequences (Figure 5). Similar results were obtained for oyster extrapallial fluid. 91% of the OTUs classified belonged to α-proteobacteria and flavobacteria (Figure 6). An equal percentage was identified as Rhodobacteraceae and Flavobacteraceae at the family level (Figure 7). Further analysis of both samples at the genera level was uninformative due to the high percentage of unidentifiable sequences in both the water (99.9%) and oyster (99.2%) samples (data not shown).

While the two most dominant bacterial families were the same between oyster and water samples and nearly identical in their proportions, there were differences observed in the less-abundant bacterial families. In particular, the water sample displayed an increased level of diversity, containing both a greater number of total families and families unique to that library (Table 2). In addition, there were instances where bacterial families common to both libraries differed in their prevalence. Most notable are the Cryomorphaceae and Flexibacteraceae, which were the 3rd and 5th most abundant classified bacterial families in the water library, but only the 13th and 15th most abundant in the oyster library. These results are not surprising since the specific microenvironment within the oyster should select for the presence of certain bacteria and against others. It is interesting that, despite different environmental conditions, the two most abundant bacterial families were nearly identical between both samples. This may be a result of the low bacterial diversity in the tank water and may not reflect the relationship between naturally occurring oyster and water bacterial communities.

Future Work

An additional 50 libraries from monthly samples taken at SERC have been prepared and sent for sequencing. This sequencing is expected to result in ~250,000 reads and provide insight into bacterial community composition and dynamics for both sample types in a more natural environment. Viral particle isolation and library construction is still under methods development, but should be soon ready to proceed with this analysis. Monthly sampling, bacterial and viral abundances, and library construction are ongoing. It is also planned to examine differences in commensal bacterial and viral community composition within healthy oysters and those affected by MSX and DERMO.

Conclusions and Project Implications

This study is a longitudinal examination of the relationship between microbial communities within the extrapallial fluid of *Crassostrea virginica* and surrounding water. Patterns of fluctuations in bacterial and viral abundance are similar between oyster and water samples; however, oyster extrapallial fluid contains a greater number of bacteria and viruses than the water. At the time of this writing, one pair of 16S libraries has been compared for tank oysters and water. This study indicates the feasibility of this experimental design; however, the low diversity within the aquarium makes it impossible to determine if the patterns observed between tank water and oysters holds true for wild samples. The findings of this study may shed light on the impacts of commensal microbial communities on oyster ecology, health, and susceptibility to disease.

Abstract

The Eastern Oyster, *Crassostrea virginica*, is an important economic and ecological resource along the east coast of North America. Since the 1950s, populations within the Chesapeake and Delaware Bays have been subject to outbreaks of MSX and Dermo, two diseases caused by parasitic protozoans. Interest in oyster microbiology has primarily focused on the causative agents of these two diseases, *Haplosporidium nelsoni* and *Perkinsus* marinus, respectively, as well as human pathogens associated with consumption of raw shellfish. Little is known about the commensal microbiome associated with oysters despite an increasing appreciation of the impacts of these communities on the biology and health of their metazoan hosts. In this study, the bacterial and viral abundance and composition within oyster extrapallial fluid and water were compared. 5 oysters and one water sample were collected from Edgewater, MD once per month beginning in October 2010. Bacterial and viral abundances were determined by epifluorescence microscopy. The bacterial community composition of oyster extrapallial fluid and surrounding water was determined for oysters maintained in an aquarium in the lab. Samples were filtered through a 0.22μm membrane filter. DNA was extracted from each 0.22μm filter and the 16S rRNA gene amplified by PCR. Samples were sequenced using the Roche 454 Genome Sequencer FLX Titanium system, and operational taxonomic unit (OTU) analysis was performed using QIIME. Bacterial and viral abundances were greater in extrapallial fluid than water for natural

samples, though both showed similar patterns of growth and decline. Oyster extrapallial fluid showed decreased diversity as compared to the surrounding water, although community composition was similar between oyster and water samples for the two largest bacterial families present.

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Table 1. A comparison of viral and bacterial abundance within and between oyster extrapallial fluid and the surrounding water. Oyster values represent mean values obtained from five oysters per sampling date. Water values are the result of a single water sample.

Sample Date	Sample Type	Viruses: Bacteria	Oyster: Water Viruses	Oyster:Water Bacteria
10/25/10	Oyster	12.79	2.00	2.08
	Water	12.40		
11/15/10	Oyster	13.34	1.64	1.56
	Water	9.59		
12/13/10	Oyster	15.16	5.03	4.22
	Water	12.08		
1/10/11	Oyster	18.18	3.74	6.57
	Water	30.94		
2/14/11	Oyster	57.02	11.05	6.99
	Water	24.91		
3/14/11	Oyster	76.33	15.43	19.63
	Water	56.50		

Table 2. A comparison of 16S rRNA metagenomic libraries from lab grown oysters and tank water.

Library	Tank Water	Tank Oyster
No. of sequences	5347	5118
No. of known phyla	7	6
No. of unique phyla	1	0
No. of known families	33	19
No. of unique families	16	1
No. of known genera	52	23
No. of unique genera	30	1

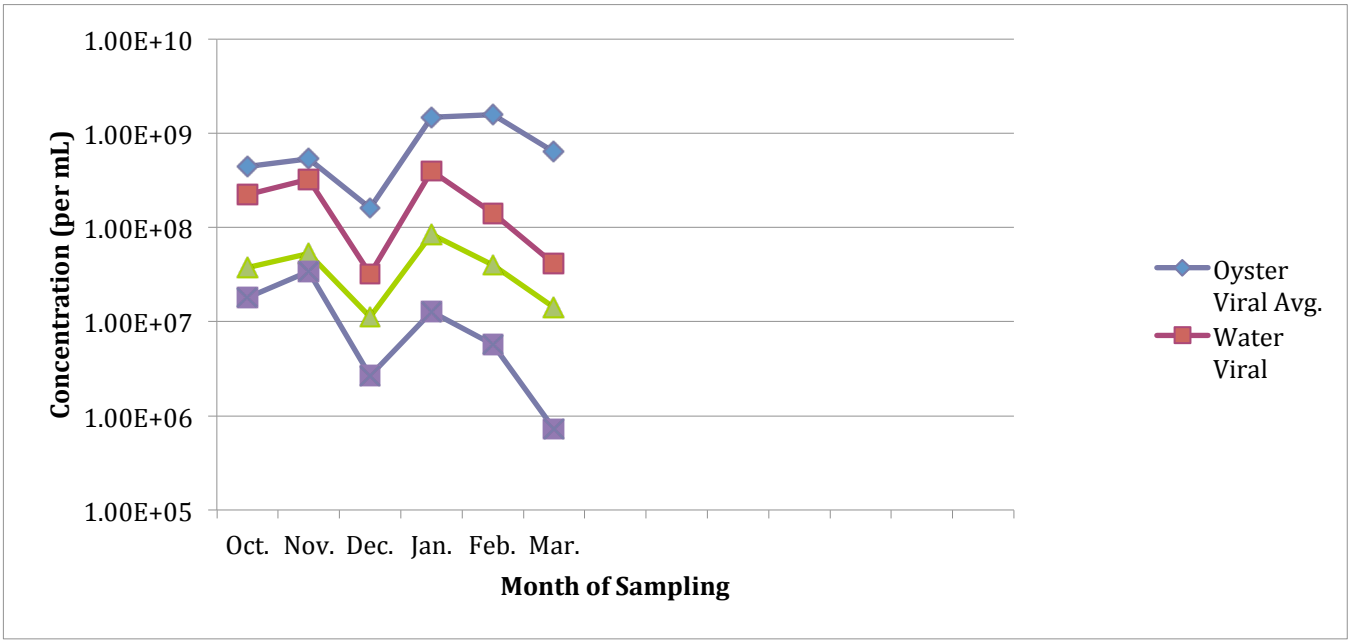

Figure 1. Bacterial and viral abundances within *Crassostrea virginica* extrapallial fluid and surrounding water from Edgewater, MD. Oyster bacterial and viral abundances represent the average value of 5 oysters sampled each month. Water bacterial and viral abundances are from a single 10L water sample.

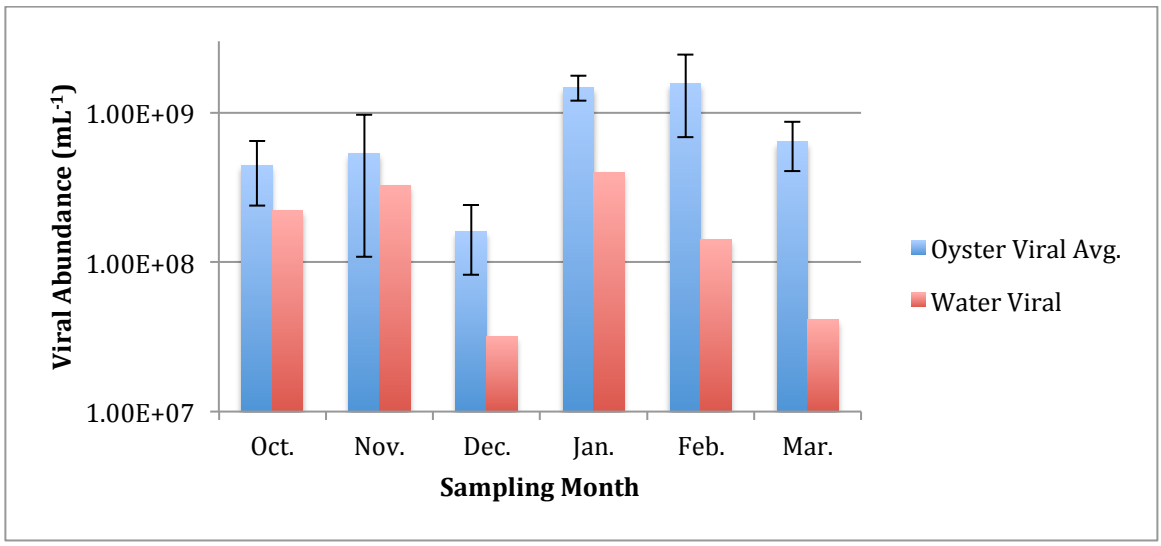

Figure 2. Viral abundances within the extrapallial fluid of *Crassostrea virginica* oysters and surrounding water from the Rhode River in Edgewater, MD. Viral abundance was determined by epifluorescence microscopy. Standard deviation was calculated for five oysters sampled each month.

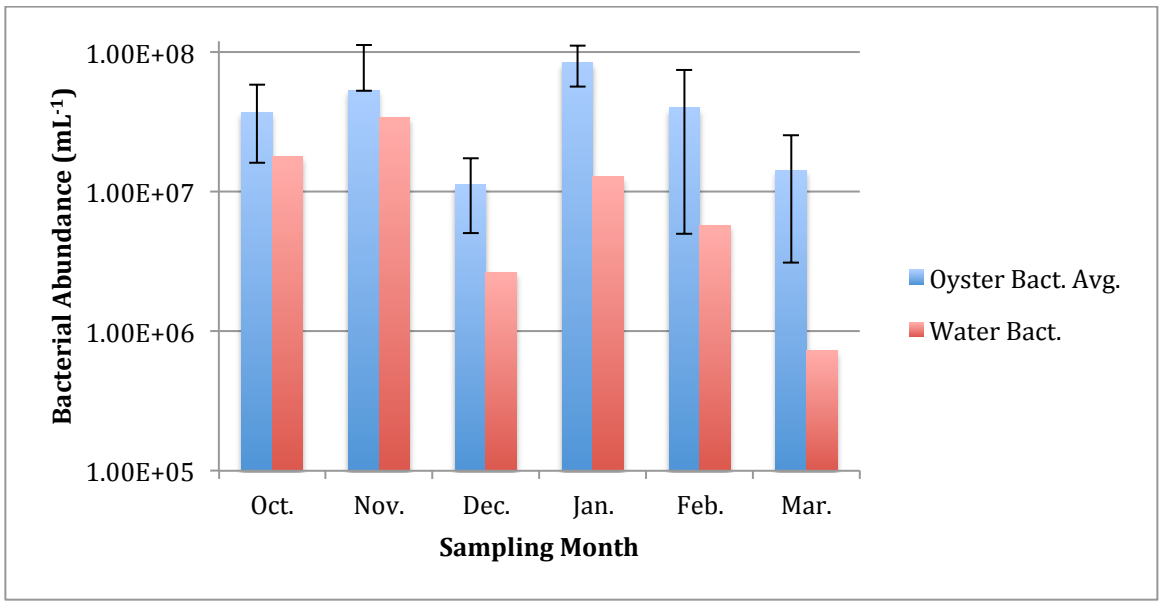

Figure 3. Bacterial abundances within the extrapallial fluid of *Crassostrea virginica* oysters and surrounding water from the Rhode River in Edgewater, MD. Bacterial abundance was determined by epifluorescence microscopy. Standard deviation was calculated for five oysters sampled each month.

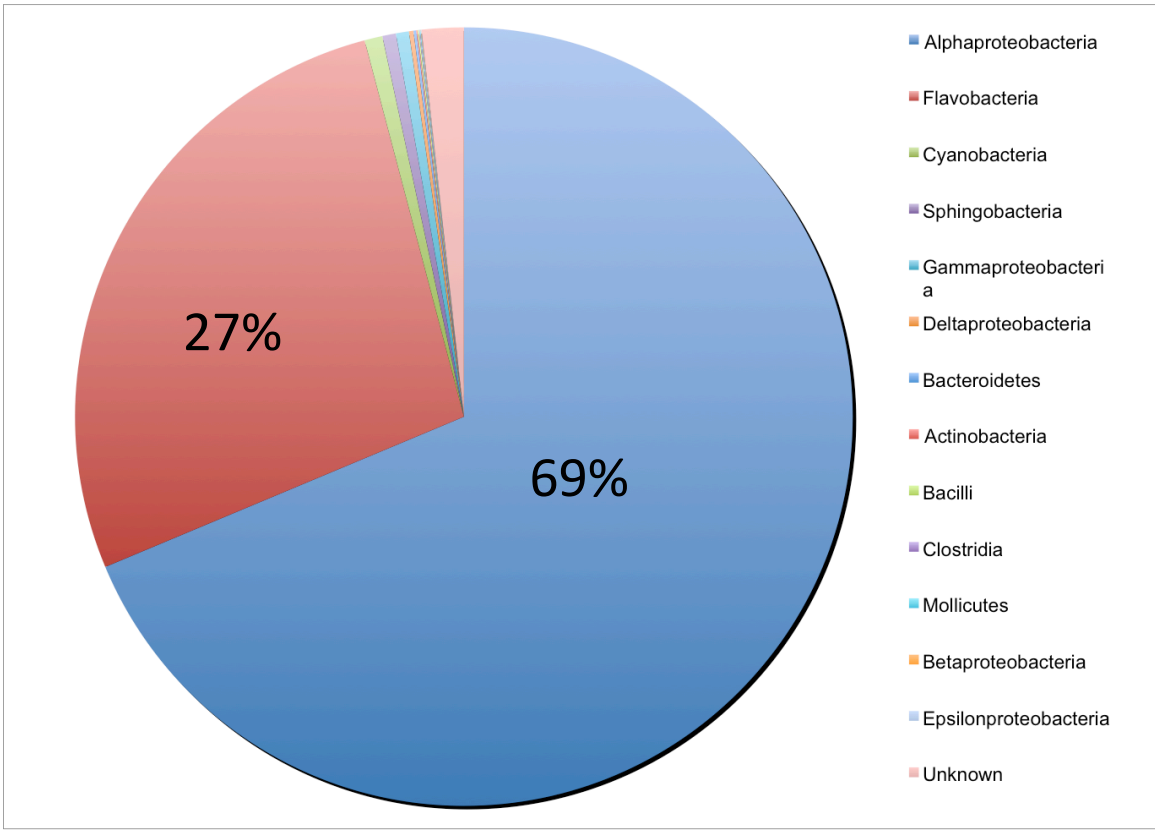

Figure 4. Bacterial composition of aquarium water at the class level. The 16S rRNA gene was amplified to create a metagenomic library and sequenced using Roche 454 pyrosequencing technology. OTU analysis was performed using the RDP classifier within the QIIME software.

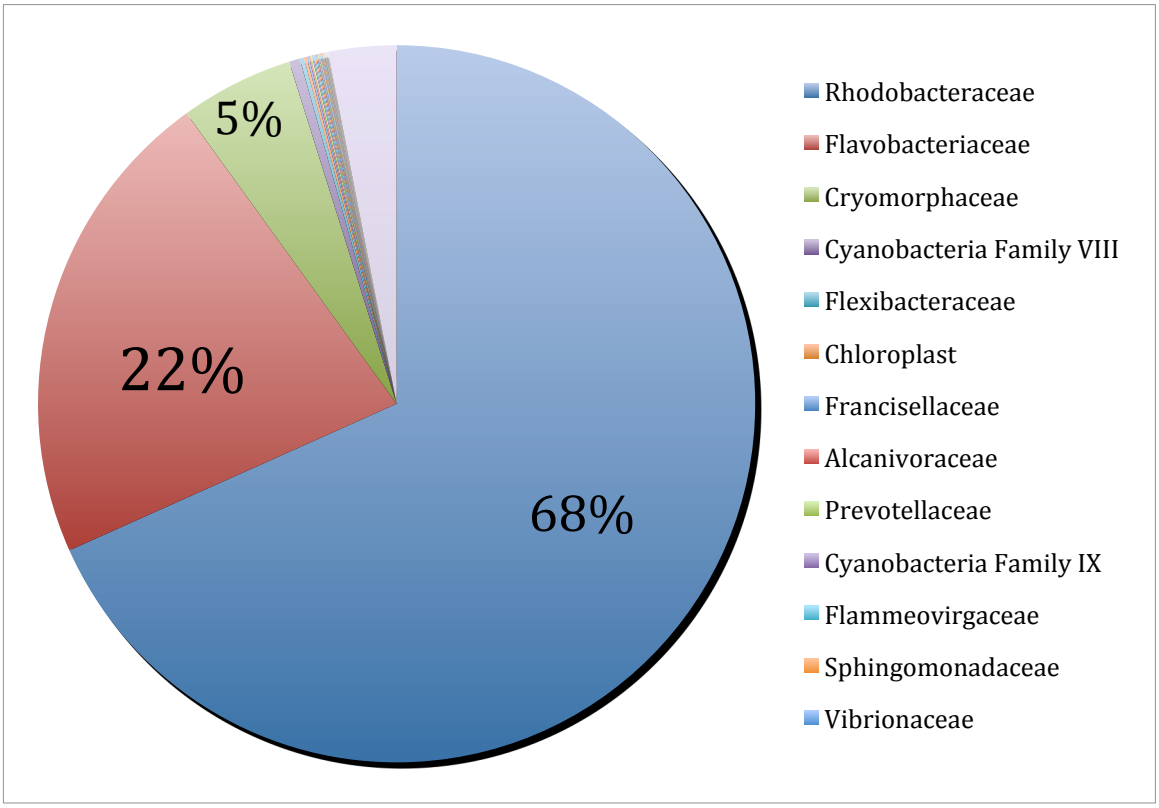

Figure 5. Bacterial composition of aquarium water at the family level. The 16S rRNA gene was amplified to create a metagenomic library and sequenced using Roche 454 pyrosequencing technology. OTU analysis was performed using the RDP classifier within the QIIME software.

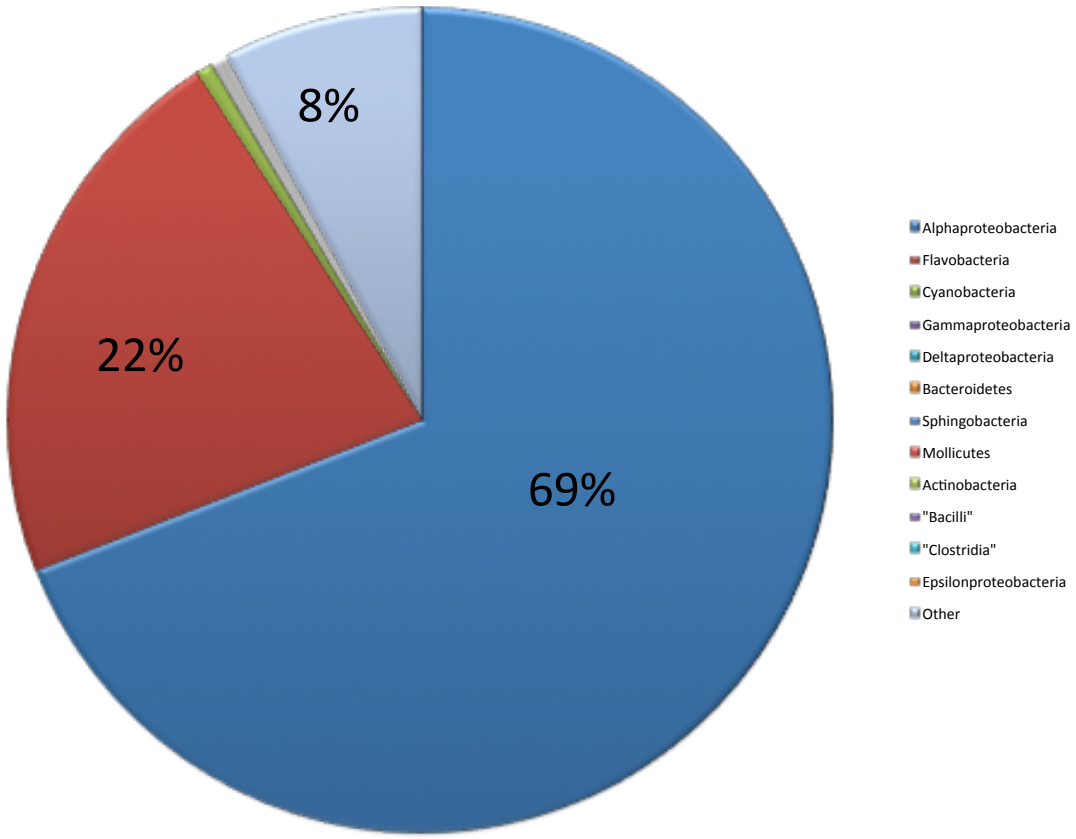

Figure 6. Bacterial composition of lab-grown oysters at the class level. The 16S rRNA gene was amplified to create a metagenomic library and sequenced using Roche 454 pyrosequencing technology. OTU analysis was performed using the RDP classifier within the QIIME software.

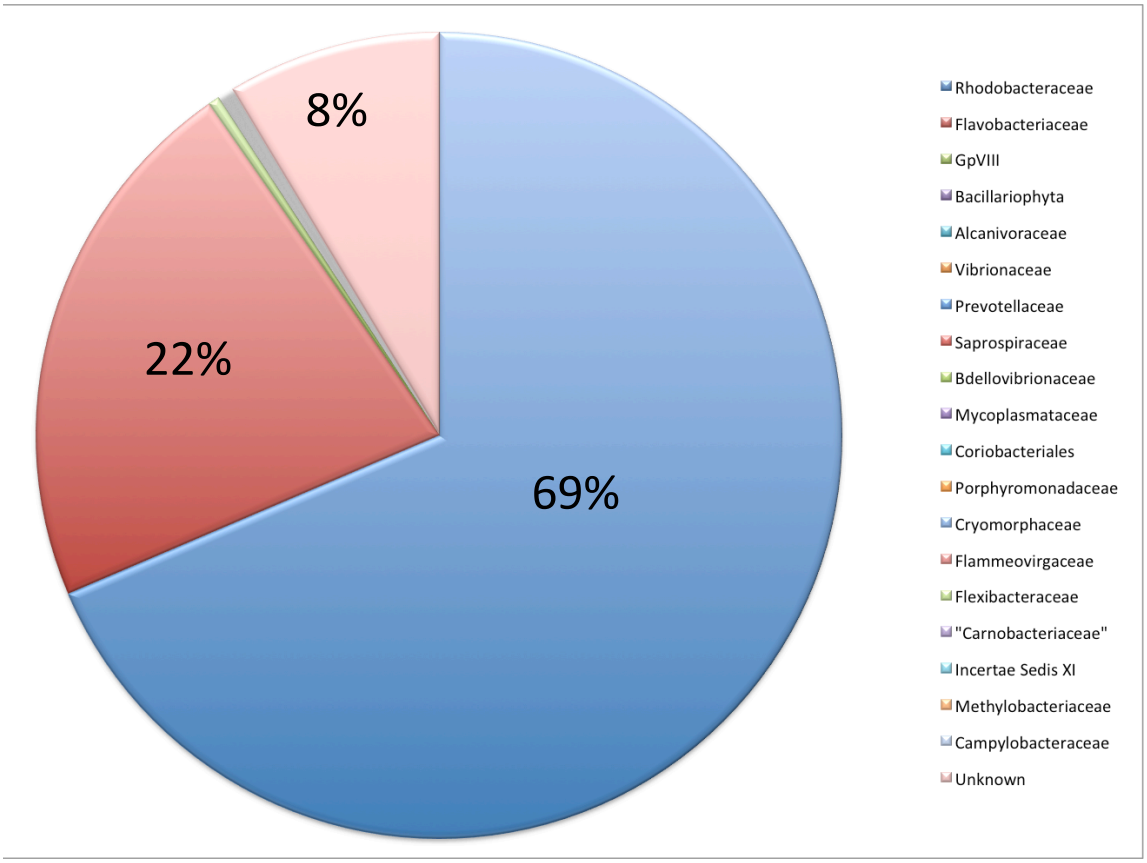

Figure 7. Bacterial composition of lab-grown oysters at the family level. The 16S rRNA gene was amplified to create a metagenomic library and sequenced using Roche 454 pyrosequencing technology. OTU analysis was performed using the RDP classifier within the QIIME software.

Quantifying the Role of Carbon Amount and Quality for Transport of Contaminants on Our Landscapes: A Watershed-Scale Model

Basic Information

Title:	Quantifying the Role of Carbon Amount and Quality for Transport of Contaminants on Our Landscapes: A Watershed-Scale Model
Project Number:	2010DE173B
Start Date:	9/1/2010
End Date:	2/28/2011
Funding Source:	104B
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Research Category:	Water Quality
Focus Category:	Non Point Pollution, Hydrogeochemistry, Nutrients
Descriptors:	None
Principal Investigators:	Shreeram P. Inamdar

Publications

1. Dhillon, G. and S. Inamdar, 2011, Quantifying the Relative Contributions of Particulate and Dissolved C to the Total Carbon Export from the Catchment: A Watershed Scale Model Progress Report, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 6 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 DWRC Spotlight on Graduate Research, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 7.

Title - Quantifying the relative contributions of particulate and dissolved C to the total carbon export from the catchment: A Watershed scale model

Investigators - Gurbir Singh Dhillon and Shreeram Inamdar

Introduction

The importance of carbon (C) for the transport of contaminants such as trace elements, pesticides, hormones, and antibiotics is well recognized. Laboratory and field studies indicate that the low polarity of hormones and some antibiotics results into moderate to strong sorption onto sediment and organic surfaces. This suggests that a greater fraction of these chemicals may either be retained in the surficial layer of soils, or may be preferentially transported with sediment when associated with POM or DOM (Kuster et al., 2004). Similar to organics, trace elements have also been found to preferentially move with particulate or dissolved organic material and sediment. Despite this recognition, very few watershed-scale studies have explicitly evaluated the relative contributions of particulate and dissolved C to the total carbon export from the catchment and the contribution of these individual C forms to contaminant transport.

The aromatic fractions of the DOC have been observed to play a key role in transport processes (Verseveld et al., 2008). This can be especially true for the agricultural runoff that contains large amount of aromatic organic compounds like humic and fulvic acids (Kelton et al., 2007). Experimental studies have also shown that contaminants such as trace elements, pesticides and antibiotics are preferentially adsorbed to the hydrophobic or humic phase of carbon and are transported with these constituents. However, the relative contributions of humic or non-humic fractions of carbon to contaminant transport are also not known. Therefore to better understand the transport potential of contaminants the quality of carbon along with its amount needs to be evaluated.

Similarly, most watershed-scale models for transport of contaminants either do not include the role of carbon in transport of contaminants, or at best, include very cursory models that do not differentiate between particulate and dissolved phases or the humic and non-humic components of carbon. Inclusion of accurate carbon transport models is critical if we want to develop realistic and reliable models for contaminant transport. This is especially important at the watershed scale, since it is the watershed-scale models that are typically used to guide watershed management strategies, inform public policy, and make regulatory decisions.

Understanding the role of particulate and dissolved forms (POC and DOC, respectively) and the humic and non-humic components of carbon for the transport of contaminants at the watershed-scale is critical for pollution mitigation and watershed management.

Questions and Objectives -

Specific questions that will be addressed are:

• What portion of the total carbon export from the watershed (on an annual and storm event basis) is constituted by – (a) particulate and dissolved carbon and (b) humic and non-humic components of carbon?

• Under what hydrologic conditions (storm events, seasons, wet/dry moisture conditions) are the exports of various forms of carbon highest?

• What are the temporal patterns of particulate carbon during events? How does the amount and patterns vary across events of different magnitude and seasonal timing?

• What are the points of origin and key hydrologic flow paths responsible for the exports of particulate carbon in the watersheds?

• How does the amount and concentration of particulate organic carbon vary with the catchment scale?

• How do the amounts of various forms of carbon differ in the agricultural watershed compared to the forested watershed?

• Develop a numeric, GIS-based, watershed-scale model that can simulate the fate and transport of various forms of carbon (esp. POC) in surface and subsurface runoff. This model will be tested from the data collected from the two study watersheds.

Methodology

Experimental watershed sites -The forested watershed site is located in the Fair Hill Nature preserve in Cecil County, MD (about 15 minutes' drive from the UD campus). The intensively instrumented study watershed is 76 ha in size and is drained by a first order stream. Land use in the watershed is primarily forested. In addition to a discharge flume and ISCO sampler at the 76 ha outlet (ST12) and 12 ha subwatershed outlet (ST3) the watershed contains weather station and groundwater wells.

The agricultural watershed is located on agricultural fields near Middletown, DE (New Castle County). The watershed is drained by a first order drainage way (~ 10 ha area). Land use is row crop agriculture with poultry litter application scheduled for spring 2011.

Watershed sampling and analyses -Runoff samples at both watersheds will be collected at the watershed outlets using automated ISCO samplers during storm events. The samples will be immediately filtered using 0.45 µm Millipore filter to partition into dissolved (passing through the filter) and particulate (retained on the filter) forms. The material retained on the filter will contain both mineral sediment and organic matter. The amount of carbon in

dissolved and particulate samples will be determined using the Elementaar total organic carbon (TOC) analyzer in the Soils Laboratory at UD.

Humic and non-humic fractions for the dissolved and particulate samples will be determined using novel spectrofluorometric techniques (McKnight et al, 2001; Weishaar et al , 2003) on the Horiba Jobin Yvon Fluoromax fluorometer available in Inamdar laboratory at UD.

Export budgets for various forms of the carbon will then be computed by multiplying the individual component concentrations with the stream flow discharge measured by the discharge flumes.

Initial Results

Five events have been collected and sampled. The samples have been submitted to Soils Laboratory, UD for determination of Total carbon in dissolved and particulate samples and the results are awaited. The hydrographs of some of the events along with the variation in concentration of Soil Solids are shown below –

Figure 1 – Streamflows and Soil solid concentrations for the event of September 30, 2010 for catchments ST3 and ST12

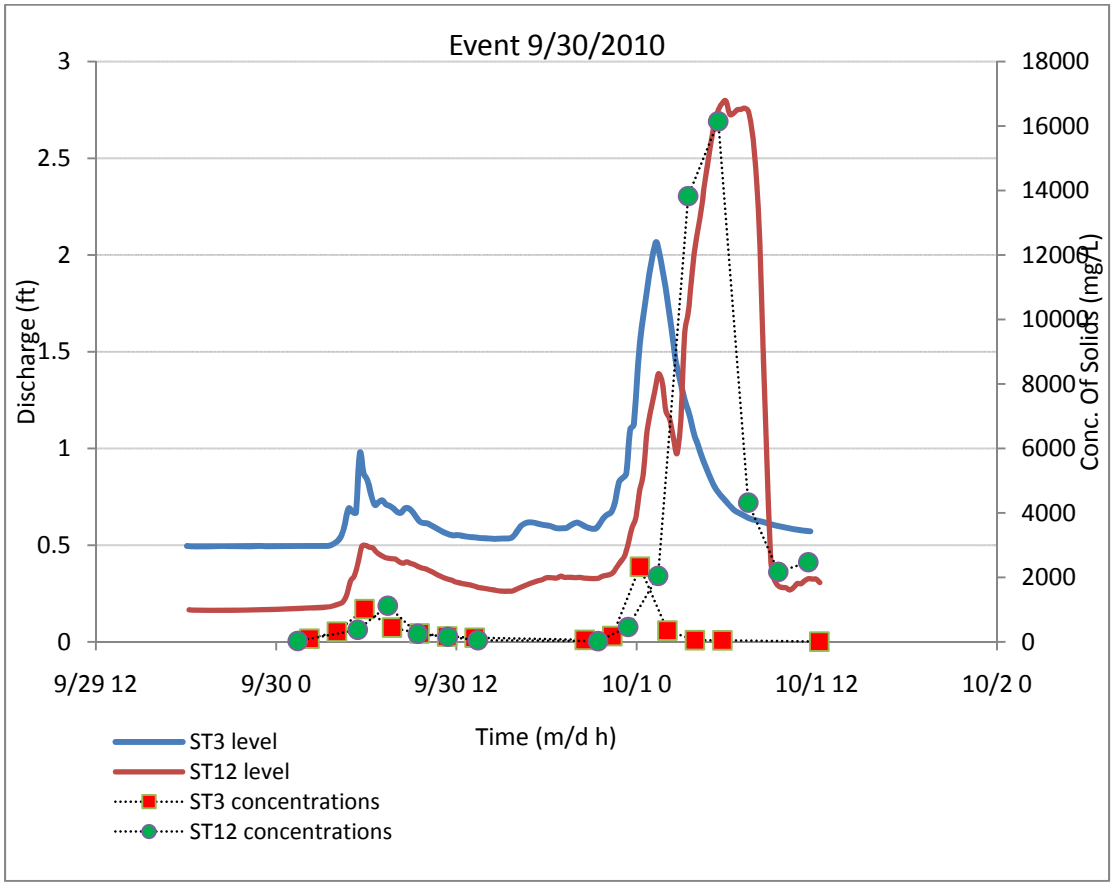


Figure 2 – Streamflows and Soil solid concentrations for the event of December 1, 2010 for catchments ST3 and ST12

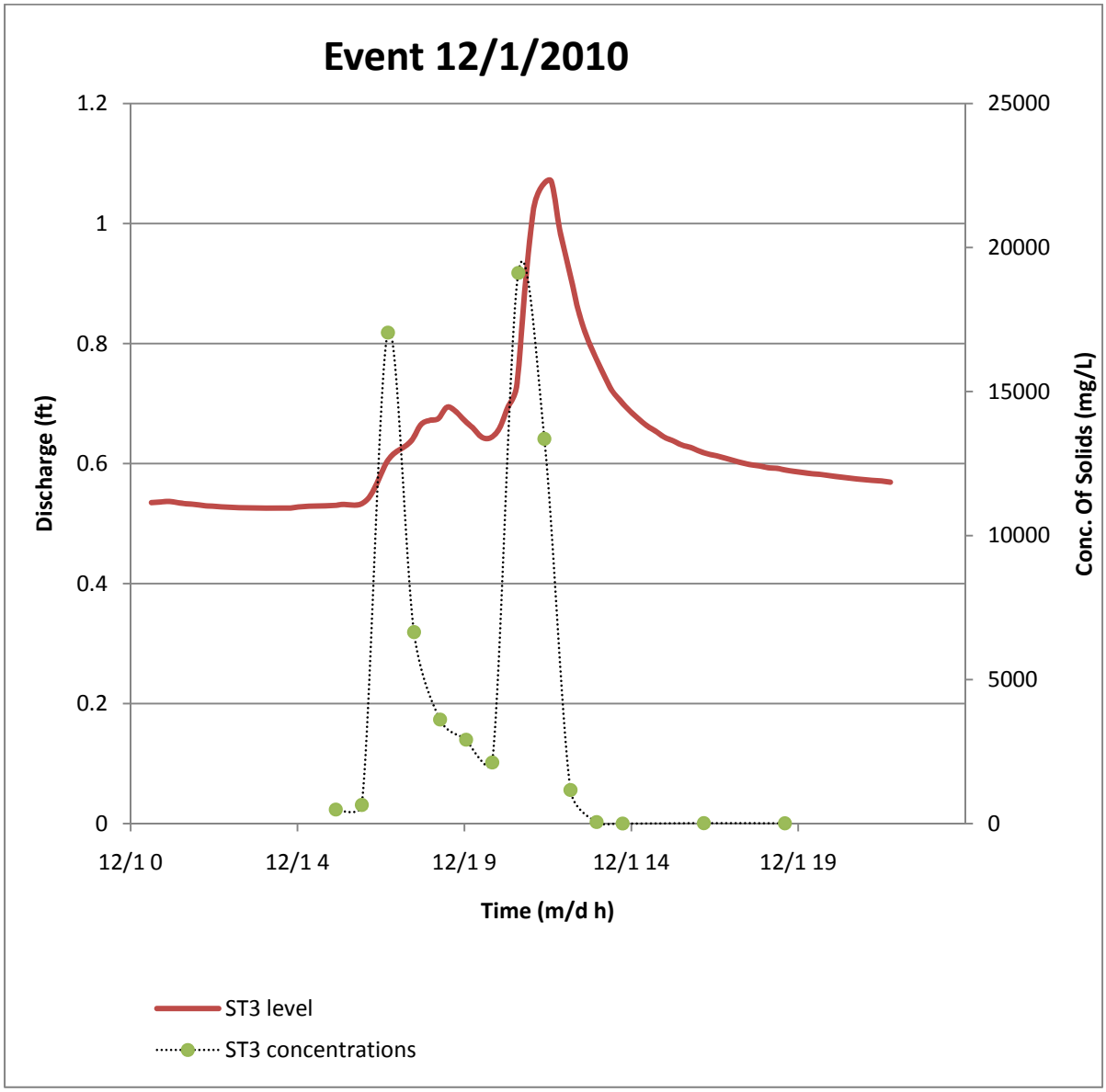
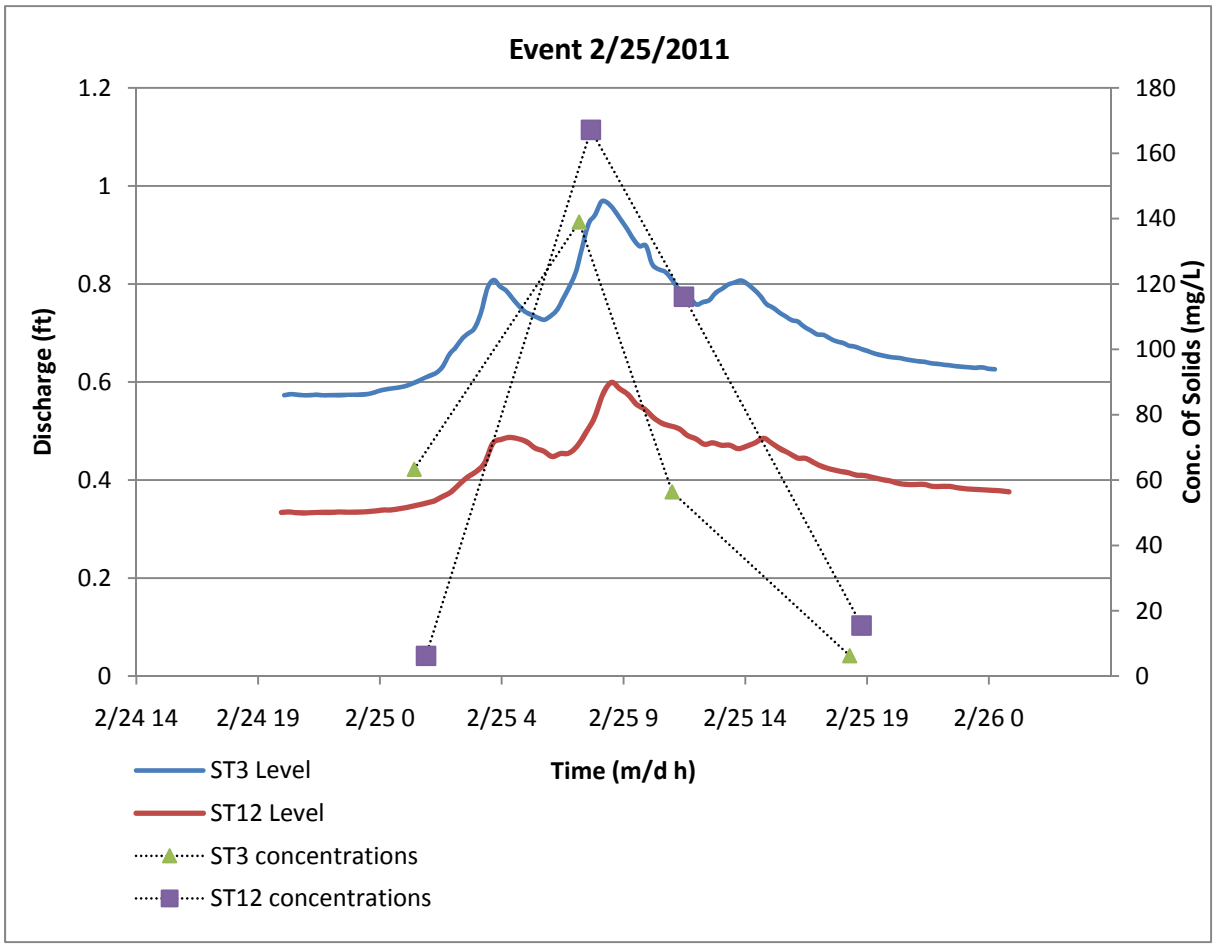


Figure 3 – Streamflows and Soil solid concentrations for the event of February 25, 2011 for catchments ST3 and ST12



From these hydrographs, we can see that the concentration of soil solids is highly correlated with discharge and tends to peak just before the peak in discharge. Also, the concentration of solids increases with the increase in catchment scale and is higher at ST12 (76 ha outlet) than at ST3 (12 ha outlet).

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Oyster Restoration Efforts at Delaware Inland Bays: Utilizing RIP-RAP as a Substrate for Oysters

Basic Information

Title:	Oyster Restoration Efforts at Delaware Inland Bays: Utilizing RIP-RAP as a Substrate for Oysters
Project Number:	2010DE174B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Biological Sciences
Focus Category:	Ecology, Water Quality, Non Point Pollution
Descriptors:	None
Principal Investigators:	Gulnihal Ozbay, Jasmine Porter

Publications

1. Porter, J. and G. Ozbay, 2011, Oyster Restoration Efforts at Delaware Inland Bays: Utilizing RIP-RAP as a Substrate for Oysters, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 2 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 5.

Undergraduate Internship Project #1 of 12 for FY10

Intern ***Jasmine Porter's*** project, sponsored by the ***DWRC***, was titled "Oyster Restoration Efforts at Delaware Inland Bays: Utilizing RIP-RAP as a Substrate for Oysters." She was advised by Dr. Gulnihal Ozbay of ***Delaware State University's*** Department of Agriculture and Natural Resources.

Abstract

Shellfish are considered an advantageous biological restoration tool because they cleanse the water by filtering algae and sediments out of the water column, having the ability to remove excess nitrogen and phosphorus from the environment. One oyster can filter up to 5 liters (1.3 US gal.) of water every hour (50 gal/day). The potential filtering ability of restored shellfish beds could help mitigate pollution and eutrophication problems within the watershed, if oyster abundance was increased dramatically. Over the past few decades the oyster population has declined potentially by more than 99% in the Delaware area. Declines occurred for various reasons including: Diseases (MSX and Dermo), overharvesting, eutrophication and increased human inhabitants along shorelines. Our study site in Jefferson Creek, South Bethany Delaware contained 3 shoreline habitats within a small coastal lagoon system. These locations were easily accessible (car or kayak). The Rip-Rap with oyster shorelines contained approximately 2,500 and 10-15,000 oysters. Natural recruitment of oysters is a long term goal, which will relieve human mitigation needs. Also, a large increase in oyster abundance should improve the water quality greatly. Additions of oysters to the nearby shorelines should create more complex habitat for species that utilize oyster reefs. We are studying the possible water quality improvements along the shoreline where oysters have been placed as well as the natural shorelines without oysters. We ran different water chemical analysis at three different sites (riprap with oysters (RRO), riprap without oysters (RR) and natural shoreline (NS)) and it has appeared that there were no true differences between the three sites. So although we know that oyster do filter the water we didn't see a tremendous different between the areas with oyster and the areas without.

Even though oysters filter water and remove excess chemicals from the water column, the abundance of oysters at our site (~2-10,000) may be too small to observe any differences in such a large enclosed water body. The tidal flushing in that area may have mixed the water which then contributed to inconclusive results. Many results occurred above the threshold level, we believe that this was due to eutrophication. If we can get the oyster population to grow at a stable rate, and continue to monitor the water doing various chemical and physical water quality testing, it is possible for us to tell whether or not the oysters are filtering the water as they are suppose to, thus improving the water quality of the watershed for all life forms. Water quality results during this study confirms our previous reports on excess nutrients and low dissolved oxygen stress in the areas we tested in Delaware Inland Bays.

The Use of Recycled Water for Irrigation of Turf and Landscape Plants

Basic Information

Title:	The Use of Recycled Water for Irrigation of Turf and Landscape Plants
Project Number:	2010DE177B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Irrigation, Non Point Pollution, Water Quality
Descriptors:	None
Principal Investigators:	Anastasia Chirnside, Stephanie Hahn

Publications

1. Hahn, S. and A. Chirnside, 2011, The Use of Recycled Water for Irrigation of Turf and Landscape Plants, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 9 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 4.

Undergraduate Internship Project #2 of 12 for FY10

Intern ***Stephanie Hahn's*** project, sponsored by the ***DWRC***, was titled "The Use of Recycled Water for Irrigation of Turf and Landscape Plants." She was advised by Dr. Anastasia Chirnside of the ***UD's*** Department of Bioresources Engineering.

Abstract

Water scarcity and water quality issues across the country are increasing the demand and acceptance by consumers for the use of recycled water. Agricultural and landscape irrigation is the largest user of water resources. Therefore, it is not surprising that the most common type of water reuse has been for crop irrigation and landscape irrigation in urban areas. As the demand for recycled water increases, the need for regulations and recommendations to ensure human safety and to minimize adverse environmental impacts becomes apparent. At the federal level, the Environmental Protection Agency has issued voluntary guidelines that suggest the level of treatment, the minimum quality for reuse, and the type of monitoring required.

Because of the increased use of recycled water, many states have begun to develop water reuse regulations. Due to severe water shortages and the increased use of recycled water, such states as California, Florida, Texas, and Arizona are leading the way in the development of water reuse regulations. California's regulations regarding the use of recycled water are outlined in Title 22, Code of Regulations on Water Recycling Criteria of the California Administrative Code. These regulations address the quality of the reclaimed wastewater as well as the type of equipment required to produce compliant water. Ultimately, it is the end use of the recycled wastewater that determines the level of treatment. The objective of this project is to develop a comprehensive literature review that defines, from a nation-wide perspective, where the research is at present and outlines what areas of research are needed in order to promote the use of recycled water in the future.

Characterization of Submarine Groundwater Discharge Sites in a Coastal Lagoon

Basic Information

Title:	Characterization of Submarine Groundwater Discharge Sites in a Coastal Lagoon
Project Number:	2010DE181B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At Large
Research Category:	Water Quality
Focus Category:	Water Quality, Hydrology, Nutrients
Descriptors:	None
Principal Investigators:	Alan Scott Andres, Kevin Myers

Publications

1. Myers, K. and A. Scott Andres, 2011, Characterization of Submarine Groundwater Discharge Sites in a Coastal Lagoon, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 19 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 5.
3. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 11 Issue 1 DWRC Spotlight on 2010-11 Undergraduate Internships, http://ag.udel.edu/dwrc/newsletters/Summer10Fall10/WATERNEWSco-Fall2010.pdf , p. 3.

Undergraduate Internship Project #4 of 12 for FY10

Intern ***Kevin Myer's*** project, co-sponsored by the ***DWRC*** and the ***Delaware Geological Survey*** was titled "Characterization of Submarine Groundwater Discharge Sites in a Coastal Lagoon." He was advised by Mr. A. Scott Andres of the Delaware Geological Survey.

"Throughout the course of my internship I was involved in numerous interesting activities and I learned a number of things that I probably would not have learned elsewhere. There were a lot of difficult situations and times were improvisation was necessary and frustration was inevitable, but it was one of the most rewarding experiences I have participated in to date and I am extremely pleased that I got the opportunity to take part in a program such as this one." – Kevin Myers

Abstract

Within the Indian River Bay natural submarine groundwater discharge (SGD) occurs allowing fresh water and added nutrients into the surrounding saltwater that composes the bay. For my internship I worked at Holts Landing State Park in Sussex County, Delaware. I worked closely with others to learn more about the SGD occurring in the Indian River Bay and try to quantify it. One method we used to quantify SGD within the bay was using seepage meters to capture water samples from within the bay floor; we then tested the salinities and compared them to the salinities of the natural bay water. The data showed areas that were more prone to SGD by finding areas with lower conductivities then that of the bay conductivity. Another important method that was, and will be used to quantify SGD within this region, is recording and continuously monitoring data from offshore wells. We outfitted a pontoon boat with the necessary equipment and drilled monitoring wells and CMT wells into the bay floor at many different sites. These wells will continue to be used to monitor salinity, temperature, and other water and nutrient tests. The work I contributed to will be used to better understand submarine groundwater discharge and how it is affecting the Indian River Bay.

The History and Effectiveness of Wetland Mitigation

Basic Information

Title:	The History and Effectiveness of Wetland Mitigation
Project Number:	2010DE182B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At Large
Research Category:	Social Sciences
Focus Category:	Wetlands, Economics, Law, Institutions, and Policy
Descriptors:	None
Principal Investigators:	Steven E. Hastings, Courtney Simmons

Publications

1. Simmons, C. and S. Hastings, 2011, The History and Effectiveness of Wetland Mitigation, Delaware Water Resources Center, University of Delaware, Newark, Delaware.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 5.

Undergraduate Internship Project #5 of 12 for FY10

Intern ***Courtney Simmons'*** project, sponsored by the ***DWRC***, was titled "The History and Effectiveness of Wetland Mitigation." She was advised by Dr. Steven Hastings of the ***UD's*** Department of Food and Resource Economics.

Compensatory Wetland Mitigation Regulations and Policies

by Courtney Simmons

My Research Project

Wetlands are a major natural resource, providing ecosystems necessary for sustaining wildlife, vegetation, and water hydrology, as well as contributing numerous functions that have an economic value to society. Wetlands in Delaware and across the United States are being destroyed, degraded, or threatened mainly by human development. The University of Delaware is doing its part to adequately compensate for lost wetlands by committing to a compensatory mitigation project at its College of Agriculture and Natural Resources. The project includes wetland creation, restoration, and enhancement to compensate for wetlands being destroyed in the Port of Wilmington. My research project concerns wetland functions, permit processes, and the mitigation policies behind this project and other similar projects.

Wetland Sequencing:

Before a permit is issued by the Corps of Engineers for destroying a wetland, sequencing of wetland mitigation must be completed.

1. *Avoidance of impacts. If there is a practicable alternative to destroying the wetland, then the permit may not be issued.*
2. *Minimization of any potential harm to the aquatic ecosystem.*
3. *Compensate for the loss in wetland acreage and loss of aquatic resource values and functional values*

What is Compensatory Mitigation?

Compensatory mitigation occurs when developers have to compensate for unavoidable adverse environmental impacts. There are several ways to compensate for the loss of wetlands:

1. *Preservation*
2. *Enhancement*
3. *Restoration*
4. *Creation*

Wetlands Regulations:

- *Rivers and Harbors Act 1899*—Prohibits the creation of any obstruction not authorized by congress to navigable US waters. Requires a permit for construction of piers, bridges, dams, or dikes.
- *National Environmental Policy Act (NEPA) 1969*—requires all federal agencies to prepare environmental assessments for proposed activities and prepare an environmental impact statement with proposed alternatives to the action
- *Coastal Zone Management Act 1972*—control and regulation on activities that adversely impact the coastal environment
- *"Swampbuster" Programs 1985*—designed to encourage participants in USDA Programs to adopt land management measures by linking program benefits to farming practices on highly erodible land and converted wetlands.
- *The Clean Water Act 1972*—Section 404 provides the primary federal authority for protecting the nation's wetlands and maintaining the chemical, physical, and biological integrity of the nation's waters.

Assessment of Changes in Invertebrate Populations Resulting from Wetland Restoration

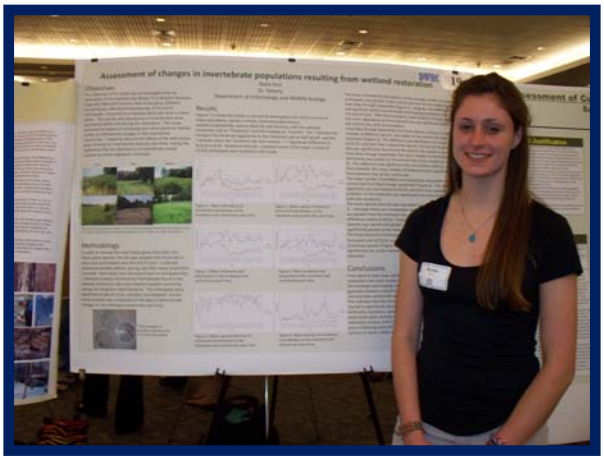
Basic Information

Title:	Assessment of Changes in Invertebrate Populations Resulting from Wetland Restoration
Project Number:	2010DE183B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Biological Sciences
Focus Category:	Ecology, Wetlands, Invasive Species
Descriptors:	None
Principal Investigators:	Douglas Tallamy, Katie Yost

Publications

1. Yost, K. and D. Tallamy, 2011, Assessment of Changes in Invertebrate Populations Resulting from Wetland Restoration, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 9 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 5.
3. Pautler, M., ed., 2010, Delaware Water Resources Center WATER E-NEWS Vol. 9 Issue 3 Spotlight on 2010-11 DWRC Undergraduate Internships, http://ag.udel.edu/dwrc/newsletters/WATERENEWS-Oct2010.pdf , p. 1.

Undergraduate Internship Project #6 of 12 for FY10



Intern ***Katie Yost's*** project, co-sponsored by the ***DWRC*** and the ***UD's College of Agriculture and Natural Resources***, was titled "Assessment of Changes in Invertebrate Populations Resulting from Wetland Restoration." She was advised by Dr. Douglas Tallamy of the ***UD's*** Department of Entomology and Wildlife Ecology.

"For my internship, I assessed the changes in invertebrate populations resulting from a wetland restoration. I gained valuable experience with collecting and indentifying arthropods and I also learned to identify various native and invasive species of plants. This internship provided me with lots of new knowledge, skills, and hands-on experience that I could not have gotten inside a classroom." – Katie Yost

Abstract

The objectives of my project were to study how the restoration of the wetland near Route 72 in Newark Delaware, originally filled with invasive reed canary grass, affected the biodiversity of terrestrial arthropods, compared to a meadow filled with diverse native plants. Each week from the end of April to mid September, I collected samples of terrestrial invertebrates found in the wetland restoration site and the meadow site by sweep net along fixed transects. The arthropods were identified to species units, counted, and weighed. A total of 13,241 arthropods were sampled in this study. From April to early June, the meadow and wetland restoration sites were similar with few significant differences in abundance, species richness, number of herbivores, number of predators, species diversity, and arthropod biomass. Following the herbicide and mowing treatments in early June, these results generally show a decline in invertebrates in the wetland restoration site and many more statistically significant differences between the two sites. The reed canary grass removal was only the first phase of the wetland restoration project, and it is expected that continued restoration of the area in following years will lead to increased arthropod abundance and richness, to levels similar to the control meadow site.

Quality of Dissolved Organic Matter in Runoff from Various Watershed Sources

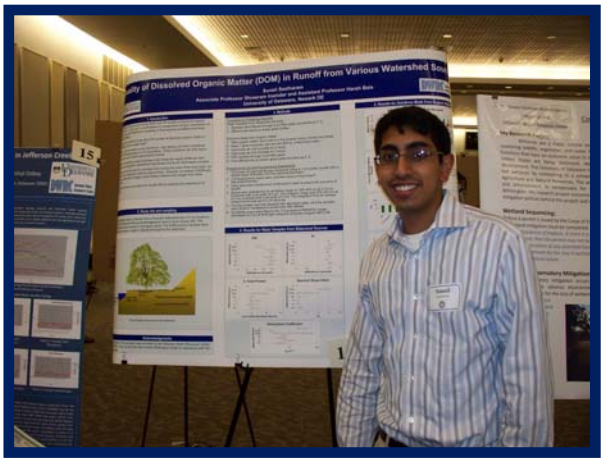
Basic Information

Title:	Quality of Dissolved Organic Matter in Runoff from Various Watershed Sources
Project Number:	2010DE185B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Hydrogeochemistry, Solute Transport
Descriptors:	None
Principal Investigators:	Shreeram P. Inamdar, Suneil Seetharam

Publications

1. Seetharam, S. and S. Inamdar, 2011, Quality of Dissolved Organic Matter in Runoff from Various Watershed Sources, Delaware Water Resources Center, University of Delaware, Newark, Delaware.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 5.

Undergraduate Internship Project #7 of 12 for FY10



Intern ***Suneil Seetharam's*** project, co-sponsored by the ***DWRC*** and the ***UD's College of Agriculture and Natural Resources*** was titled "Quality of Dissolved Organic Matter in Runoff from Various Watershed Sources." He was advised by Dr. Shreeram Inamdar of the ***UD's*** Department of Bioresources Engineering.

Abstract

Understanding the quality and quantity of dissolved organic matter (DOM) from various watershed sources is extremely important when considering possible pollution issues and adverse effects on the surrounding ecosystems. Therefore, in this study, the DOM quality was determined for 10 watershed sources as well as for solutions made from 13 different organic matter sources from throughout the watershed. The DOM quality was measured using a combination of several optical indices determined using UV-visible absorbance curves and PARAFAC modeling of three-dimensional fluorescence excitation-emission matrices (EEMs). In addition, a phenol and flavonoid quantification was completed in order to determine the dissolved organic carbon (DOC) concentration changes for the different sources. The DOM quality indices revealed several important facts about the DOM from the various watershed sources. The surficial watershed sources were more aromatic, humic like, higher in molecular weight, and had higher flavonoid and phenol concentration. The deeper sources were more bioavailable and lower in molecular weight. This is because the soil acts as a filter by adsorbing heavy, aromatic compounds onto its surface. The indices for the solutions made with organic matter from throughout the watershed presented some interesting trends. The phenol and flavonoid concentrations illustrated that the dissolved organic carbon is in high concentrations for the surficial sources, but decreases as one progresses down the soil profile.

The Impacts of Redefining Navigable Waters Under the Clean Water Act

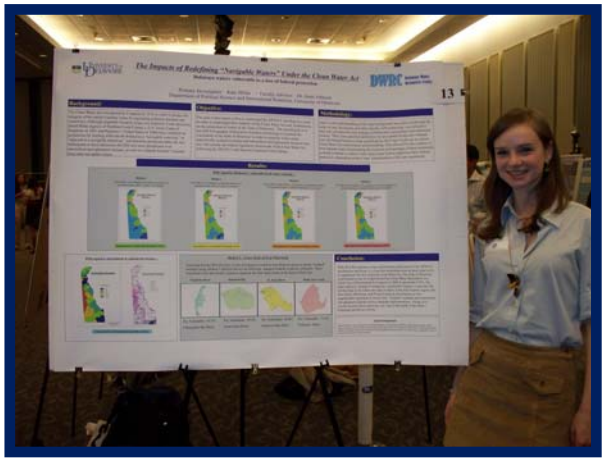
Basic Information

Title:	The Impacts of Redefining Navigable Waters Under the Clean Water Act
Project Number:	2010DE186B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Economics, Surface Water
Descriptors:	None
Principal Investigators:	Janet B. Johnson, Kate Miller

Publications

1. Miller, K. and J. Johnson, 2011, The Impacts of Redefining "Navigable Waters" Under the Clean Water Act, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 38 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 5.
3. Pautler, M., ed., 2010, Delaware Water Resources Center WATER E-NEWS Vol. 9 Issue 3 Spotlight on 2010-11 DWRC Undergraduate Internships, http://ag.udel.edu/dwrc/newsletters/WATERENEWS-Oct2010.pdf , p. 2.

Undergraduate Internship Project #8 of 12 for FY10



Intern ***Kate Miller's*** project, co-sponsored by the ***DWRC*** and the ***UD's College of Arts and Sciences*** was titled "The Impacts of Redefining Navigable Waters under the Clean Water Act." She was advised by Dr. Janet Johnson of the ***UD's*** Department of Political Science and International Relations.

"This internship with the Delaware Water Resources Center has taught me the importance of pursuing the issues that are important to me, and of using technology to help interpret and support policy." – Kate Miller

Abstract

For decades, the Clean Water Act has been the foundation for the comprehensive protection of our nation's waterways. Unfortunately, in the last ten years, two Supreme Court cases have undermined the ability of the EPA and the Army Corps of Engineers to protect intermittent and ephemeral streams, as well as so-called "isolated" wetlands, all of which make up a significant and vital portion of the country's hydrologic profile. This report examines the legal background of the cases and then utilizes GIS technology to demonstrate the potential ramifications for the waters in the State of Delaware, including both the physical and social consequences of a loss of federal protection. Mapping and measuring of intermittent and ephemeral streams by watershed indicates that roughly 21% of total stream miles in Delaware would lose protections. Four separate methods created to define the term "isolated" allowed for the identification (by watershed) of the State's freshwater wetlands vulnerable to a loss of protection. The mapping of these definitions shows that between 32-49% of Delaware's freshwater wetlands could be outside the realm of federal Clean Water Act jurisdiction.

An Analysis of the Impact of Marcellus Shale Development on Water Resources in Pennsylvania

Basic Information

Title:	An Analysis of the Impact of Marcellus Shale Development on Water Resources in Pennsylvania
Project Number:	2010DE187B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Non Point Pollution, Groundwater
Descriptors:	None
Principal Investigators:	Janet B. Johnson, Aidan Galasso

Publications

1. Galasso, A. and J. Johnson, 2011, An Analysis of the Impact of Marcellus Shale Development on Water Resources in Pennsylvania, Delaware Water Resources Center, University of Delaware, Newark, Delaware.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 4.

Undergraduate Internship Project #9 of 12 for FY10

Intern ***Aidan Galasso's*** project, co-sponsored by the ***DWRC*** and the ***UD's College of Arts and Sciences*** was titled "An Analysis of the Impact of Marcellus Shale Development on Water Resources in Pennsylvania." He was advised by Dr. Janet Johnson of the ***UD's*** Department of Political Science and International Relations.

Abstract

The Marcellus Shale is a natural gas bearing shale formation that underlies much of Pennsylvania as well as parts of New York, West Virginia and Ohio. The shale is withdrawn by a practice called hydro-fracking. This process involves injecting millions of gallons of water, sand and chemicals into the ground to free up natural gas. There is concern that the chemicals used in the fracking process, many of which are toxic, will harm the environment. Waste water from drilling is high in Total Dissolved Solids and can have radioactive material, thus it is potentially hazardous to drinking water supplies if it gets into streams. The EPA is currently studying if fracking fluids that remain in the ground can get into underground sources of drinking water. It was found that the presence of Marcellus Shale in district and being a member of the Senate are best predictors of who received contributions from the gas industry.

The Prevalence of Pathogenic Bacteria in Delmarva Waters from a Virus Point of View

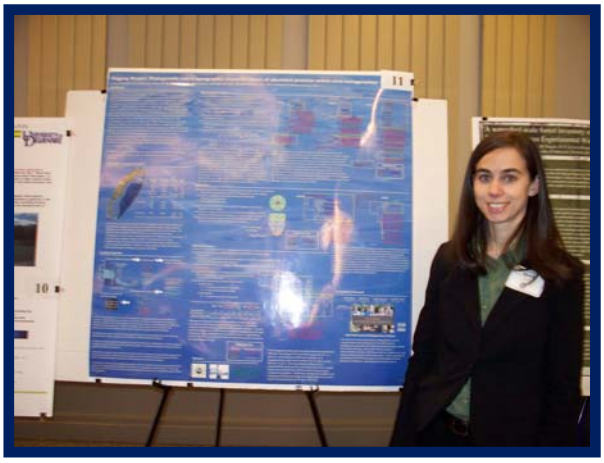
Basic Information

Title:	The Prevalence of Pathogenic Bacteria in Delmarva Waters from a Virus Point of View
Project Number:	2010DE188B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Ecology, Surface Water, Water Use
Descriptors:	None
Principal Investigators:	Eric Wommack, Mara Hyatt

Publications

1. Hyatt, M. and E. Wommack, 2011, The Prevalence of Pathogenic Bacteria in Delmarva Waters from a Virus Point of View, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 5 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 4.

Undergraduate Internship Project #10 of 12 for FY10



Intern ***Mara Hyatt's*** project, co-sponsored by the ***DWRC*** and the ***UD's College of Earth, Ocean, and Environment***, was titled "The Prevalence of Pathogenic Bacteria in Delmarva Waters from a Virus Point of View." She was advised by Dr. Eric Wommack of the ***UD's*** Department of Plant and Soil Sciences.

Abstract

Until recently, knowledge of viral gene content was restricted to studies performed on a limited number of cultivable viruses. In contrast, the vast majority of viruses is not readily cultivated and cannot be investigated by culture-dependent techniques. With the emergence of metagenomics, it has become possible to gather information about these viruses. This study examined Ribonucleoside Reductase (RNR), a key component in nucleotide metabolism that is found in many dsDNA viruses. Sequences annotated as RNR were found in several dsDNA viral metagenomes and one ssDNA viral metagenome, namely from the Chesapeake Bay, Dry Tortugas, Gulf of Maine, Scripps Pier, and Mission Bay. BLAST hits generated from the reads showed high similarities between the annotated sequences and known viral RNR genes. The annotated RNR sequences were clustered by homology across libraries, and 14 of the 18 clusters created had top functional hits to viral RNR genes. Examination of the sequences in the Geneious bioinformatic software package enabled the construction of consensus sequences and multiple sequence alignments (MSA) of nucleotide and translated consensus sequences, thus providing a closer look at the gene. From the nucleotide MSA, primers were designed and tested against Chesapeake Bay and Delaware Bay viral concentrates for amplification. Polymerase chain reaction (PCR) and gel electrophoresis were successful in revealing putative RNR genes as bands of the expected amplicon size were observed. Phylogenetic analysis reveals that each library contained sequences from more than one clade. In addition, the sequences were more closely related to each other than to reference sequences.

A Watershed Scale Forest Inventory of the Fair Hill Natural Resource Management Area

Basic Information

Title:	A Watershed Scale Forest Inventory of the Fair Hill Natural Resource Management Area
Project Number:	2010DE189B
Start Date:	6/1/2010
End Date:	2/1/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Hydrogeochemistry, Surface Water
Descriptors:	None
Principal Investigators:	Delphis Levia, Michelle Lepori-Bui

Publications

1. Lepori-Bui, M. and D. Levia, 2011, A Watershed Scale Forest Inventory of the Fair Hill Natural Resource Management Area, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 4 pages.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 4.

Undergraduate Internship Project #11 of 12 for FY10

Intern ***Michelle Lepori-Bui's*** project, co-sponsored by the ***DWRC*** and the ***UD's College of Earth, Ocean, and Environment***, was titled "A Watershed Scale Forest Inventory of the Fair Hill Natural Resources Management Area." She was advised by Dr. Delphis Levia of the ***UD's*** Department of Geography.

"Through this internship, I have learned a lot of hydrology field research techniques and skills, including surveying, collecting and processing water samples, and data analysis. But most importantly, I got to experience being part of a research team in which everyone is willing to help each other out and most projects get accomplished through a group effort. I have gained so much knowledge and experience from everyone I worked with on this project that will definitely be useful in my future research and career goals." – Michelle Lepori-Bui

Abstract

The aim of the research is to begin a complete watershed inventory of every tree within the 12 ha catchment at the Fair Hill Natural Resource Management Area. GPS was used to locate tree points and standard inventory techniques were used to characterize the trees surveyed. The database was then input into a GIS framework for mapping. Of the > 600 trees sampled to date the average stand density was approximately 220 trees ha^{-1}, and the total basal area is 26.9 m^2 ha^{-1}. The average (± 1 SD) characteristics for the sampled trees were as follows: height was 22.3 m ± 11.3, diameter at breast height was 31.5 cm ± 23.7, and bark thickness was 6.2 mm ± 7.2. The partial inventory completed to date shows the prominence of *Fagus grandifolia* (American beech), suggesting that this shade tolerant species will continue to dominate the experimental plot and surrounding areas for decades to come.

Resurfacing Silver Brook Stream and Comparison to Connected Water Bodies

Basic Information

Title:	Resurfacing Silver Brook Stream and Comparison to Connected Water Bodies
Project Number:	2010DE190B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Ecology, Solute Transport, Non Point Pollution
Descriptors:	None
Principal Investigators:	Chad Nelson, Hannah Starke

Publications

1. Starke, H. and C. Nelson, 2011, Resurfacing Silver Brook Stream and Comparison to Connected Water Bodies, Delaware Water Resources Center, University of Delaware, Newark, Delaware.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 5.

Undergraduate Internship Project #12 of 12 for FY10

Intern ***Hannah Starke's*** project, co-sponsored by the ***DWRC*** and the ***UD's Department of Plant and Soil Sciences***, was titled "Resurfacing Silver Brook Stream and Comparison to Connected Water Bodies." She was advised by Mr. Chad Nelson of the ***UD's*** Department of Plant and Soil Sciences.

Abstract

Since the University of Delaware's acquisition of the Chrysler plant, interest in "day-lighting" an underground stream that runs through the property has emerged. The stream runs roughly northwest to southeast and is known as Silver Brook Stream. In the interest of the restoration of Silver Brook as well as the future water quality of the stream, documentation and assessment of surrounding tributaries and connected water bodies is informative and essential. For this study I utilized a combination of longitudinal and sectional studies of the Christiana Creek (the closest open waterway to Silver Brook stream) and several of its tributaries. These studies involved identifying bank profiles, current patterns, and inventorying plant and animal communities present. Through the comparison of related case studies I sought to create an analysis of the existing conditions of the sites as well as an informed proposal that matches stream restoration techniques with an in-depth study of connected water bodies. After completing these studies, a conclusion was drawn about the general health of the surrounding water bodies, as well as Silver Brook stream. As part of the University's green initiative I would highly recommend daylighting Silver Brook and restoring its original natural morphology as observed from historical aerial photography. Surrounding water bodies showed considerable evidence of invasive plant growth as well as diminishing water quality and were therefore inadequate frames of reference for this project. The University should also consider the impact of daylighting portions of Silver Brook found in a community upstream to the Chrysler plant.

UD Watershed Team for Ecological Restoration

Basic Information

Title:	UD Watershed Team for Ecological Restoration
Project Number:	2010DE198B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Surface Water, Management and Planning
Descriptors:	None
Principal Investigators:	J. Thomas Sims, Anastasia Chirnside, Gerald Kauffman, Thomas McKenna, Maria Pautler

Publication

1. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 11 Issue 1 The UD WATER PROJECT, http://ag.udel.edu/dwrc/newsletters/Summer10Fall10/WATERNEWSco-Fall2010.pdf , p. 2.

UD WATER Project for FY10

A three-part breakout of a work plan was devised for the Cool Run Watershed. The following work was accomplished:

1) Intern ***Melanie Allen*** worked on "Assessing the Biodiversity of Aquatic Macroinvertebrates Residing in the Cool Run Watershed" with Dr. Judith Hough-Goldstein of the ***UD's*** Department of Entomology and Wildlife Ecology.

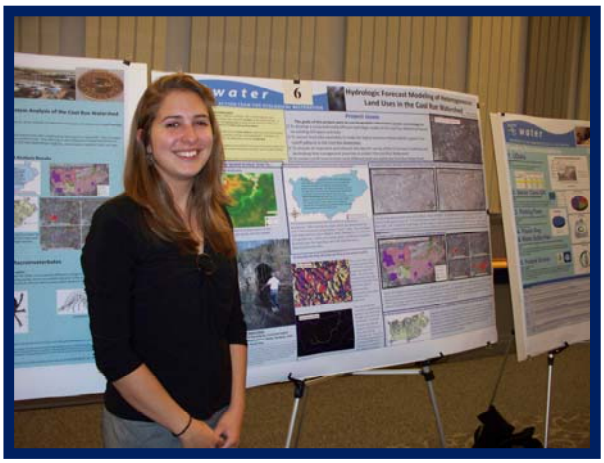
Abstract

The study of aquatic insects is known as aquatic entomology. Aquatic insects are essential to fresh water ecosystems and makes up a large portion of the study of aquatic ecology. Not only are aquatic insects imperative indicators of stream health, but they also serve as food for fish, amphibians, shorebirds, waterfowl, and other animals, often converting plant material into animal tissue. Because aquatic invertebrates are readily affected by the environment around them, they are commonly used for scientific research. Areas are often surveyed before major developments are established such as sewage treatment plants or power-plant cooling facilities to have a proper understanding of the prior richness of biodiversity which will indeed be effected once chemical and physical characteristics of the environment are altered. Aquatic insects are abundant in numbers, have short life cycles, and are directly affected by changes in water chemistry and flow. Due to these factors, along with the relative ease of sampling, aquatic insects are excellent indicators of the aquatic ecosystem health. A mutation in a species composition is relatively easy to detect and can then be used to assess stream decline or recovery. Bottom dwelling insects and aquatic invertebrates maintain a relatively stable position in the aquatic environment, so by measuring changes in their communities both qualitatively and quantitatively will reflect various degrees of quality shifts resulting from the addition of pollutants to the water.

The Cool Run Tributary of the White Clay Creek Watershed lies within the Delaware River Basin. The Delaware River Basin covers 13,539 square miles and is fed by 216 tributaries draining parts of New York, Pennsylvania, New Jersey, and Delaware. The White Clay Creek (WCC) is a sub-watershed of the Christina River Basin, which is a sub-basin of the Delaware River Basin. In October 2000, Congress approved the addition of a section of the lower Delaware River and the White Clay Creek to the National Wild and Scenic Rivers System. The White Clay Creek Wild and Scenic Rivers System Act designated the entire watershed, approximately 190 miles of segments and tributaries, as components of the national system. The creek flows from southeastern Pennsylvania to northwestern Delaware, through the UD campus and eventually joins the Christina River, a tributary to the Delaware River.

I created a reference collection of the biodiversity of aquatic macroinvertebrates in the UD Experimental Watershed at Newark Research and Education Center of the University of

Delaware College of Agriculture and Natural Resources from samples collected during the Summer of 2010. (credit to Bonnie McDevitt) for future interns to utilize as a baseline of data then completed a Winter sampling to add to the reference collection.



2) Intern ***Melissa Luxemberg*** worked on "Hydrologic Forecast Modeling of Heterogeneous Land Uses in the Cool Run Watershed" with Dr. John Mackenzie of the ***UD's*** Department of Food and Resource Economics.

Abstract

Objectives: The objectives for my project were as follows: to develop a computationally efficient hydrologic model of the Cool Run Watershed based on existing GIS layers and data, to correct local data anomalies to make the Digital Elevation Model (DEM) support true runoff patterns in the Cool Run Watershed, to compile all important and relevant GIS data for use by others in forecast modeling and developing best management practices to protect the Cool Run Watershed, and to model runoff impacts from each different land use within the Cool Run Watershed.

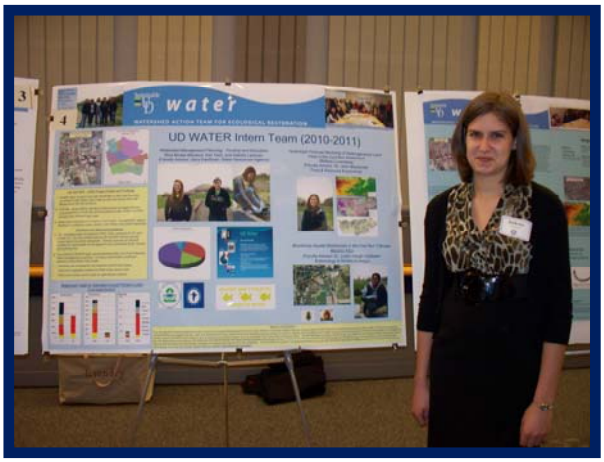
Methods: Ultimately, I used a geographic information system to collect and manipulate data within the Cool Run Watershed in order to analyze runoff percentages and sources. I obtained the following data: land use, watershed boundaries, digital elevation model, flow direction, flow accumulation, roads, railways, soils, impervious surfaces, streams, and Delaware aerial data. Specifically, I used ArcMap's spatial analyst hydrology tools to accomplish many tasks by tweaking and manipulating this data in order to draw conclusions about the watershed. Additionally, I did some fieldwork to discover and eliminate the differences between the true real-world model and the GIS computer generated hydrologic model.

Results: In my analysis I was able to import a 10x10 meter resolution digital elevation model of the study area. I used this model, along with hydrologic unit coded watershed data, to delineate the true boundary of the Cool Run Watershed. Generating flow direction and flow accumulation rasters from these data using GIS hydrology tools set the building blocks upon which I could change the data in other ways. I was able to combine stream channels inferred from the flow accumulation raster with actual stream features as targets for runoff modeling. With these, I modeled runoff impacts from four specific land uses within the watershed: commercial, residential, agricultural, and forest/brush. Finally, I obtained data on impervious surfaces, and found research to suggest these are the most harmful to most watersheds in terms of pollutants and excess water flow.

Conclusion: There now is an array of data I have complied, all dealing with hydrologic aspects of the Cool Run Watershed. This can be used in future research to mitigate the effects of storm

water runoff and pollutants. From my research, it is clear that impervious surfaces and commercial land use contribute most to runoff in the Cool Run Watershed. Best management practices focused around these areas can be implemented, which will also aid in protecting the environment of the Cool Run as a whole.

3) Interns ***Rina Binder-Macleod, Dakota Laidman,*** and ***Kim Teoli*** worked on "Watershed Plan for Cool Run: Funding and Education" with Mr. Gerald Kauffman of the ***UD's Institute for Public Administration Water Resources Agency***.



Abstract

Our research goal was to develop a watershed plan for the Cool Run Watershed in Newark, Delaware, in accordance with EPA standards in order to be eligible for Section 319 funding. Our team built upon the work of former interns, who completed parts "a" through "c." We focused on part "d," funding, and part "e," education/public outreach. For public outreach and education, we recommend increased signage, social media, storm drain stenciling, putting an article in the review, and advertising on the student television network. For funding we recommend contributions from UDairy Creamery, Senior Class Gift, parking fees, plastic water bottles and plastic bags fee, and grants.

Information Transfer Program Introduction

None.

Education and Outreach for the Delaware Wetlands

Basic Information

Title:	Education and Outreach for the Delaware Wetlands
Project Number:	2010DE178B
Start Date:	6/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At large
Research Category:	Not Applicable
Focus Category:	Wetlands, Education, None
Descriptors:	None
Principal Investigators:	Kathryn O'Connell, Kristin Berry

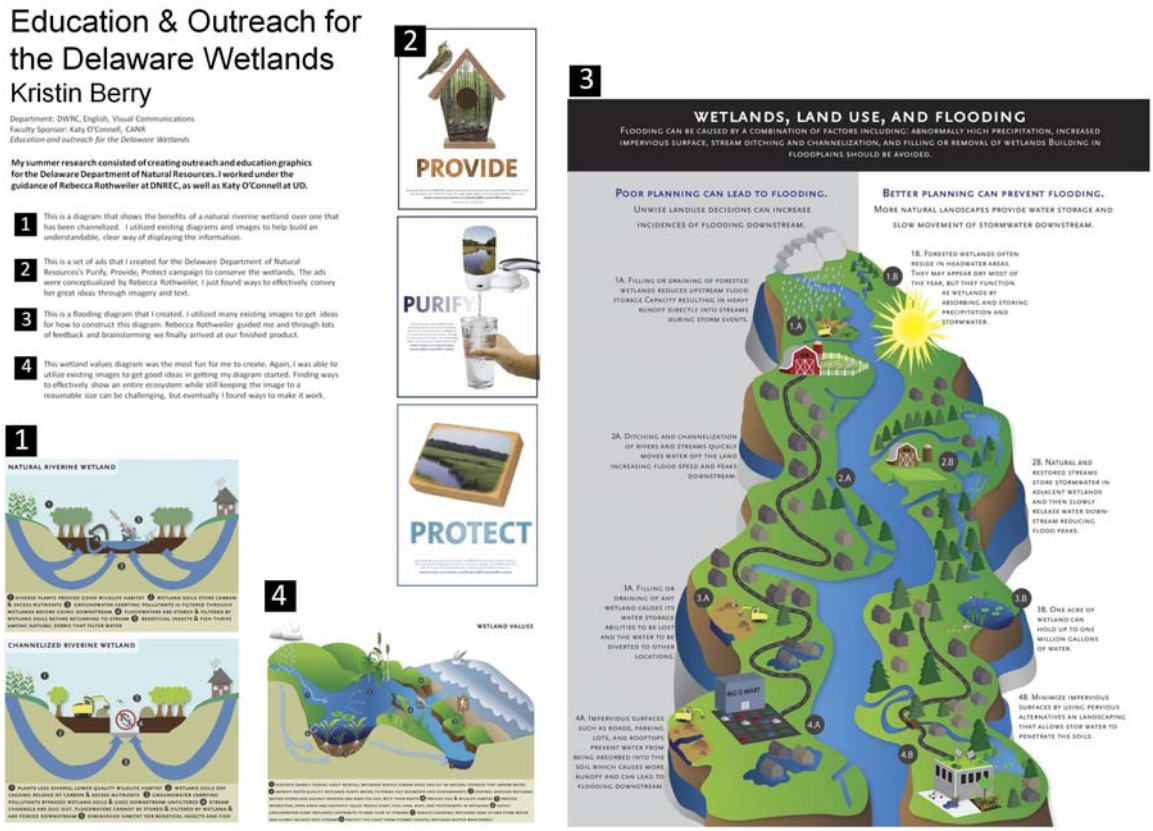
Publications

1. Berry, K., R. Rothweiler and K O'Connell, 2011, Education and Outreach for the Delaware Wetlands, Delaware Water Resources Center, University of Delaware, Newark, Delaware.
2. Pautler, M., ed., 2010, Delaware Water Resources Center WATER NEWS Vol. 10 Issue 2 Introducing Our 2010-11 Spring Interns, http://ag.udel.edu/dwrc/newsletters/Winter09Spring10/WATERNEWSco-Spring2010.pdf , p. 4.

Undergraduate Internship Project #3 of 12 for FY10

Intern ***Kristin Berry's*** project, co-sponsored by the ***DWRC*** and the ***Delaware Department of Natural Resources and Environmental Control***, was titled "Education and Outreach for the Delaware Wetlands." She was advised by Rebecca Rothweiler of the Delaware Department of Natural Resources and Environmental Control and Katy O'Connell of the ***UD's*** Office of Agricultural Communications, College of Agriculture and Natural Resources.

"Our experience with the DWRC Internship program was fantastic! Maria, Katy, and Dr. Sims were supportive of our working relationship with the undergraduate. Kristin's artistic skills and ability to represent abstract ecological concepts through the application of her software and design intuition are excellent. She created illustrations relating to wetland health, wetland habitats and functions, and wetlands on a watershed context to inform the public of wetland services, functions, and vulnerability. The style of her pieces is clear and attractive enough to garner the attention of and be readily absorbed by laypersons. It was intriguing to work with her as she represents the cutting edge of her field. I hope her experience representing natural resources will inspire her to use her talents to support the environment in the future." – Rebecca Rothweiler



DWRC Information Transfer

Basic Information

Title:	DWRC Information Transfer
Project Number:	2010DE197B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	At Large
Research Category:	Not Applicable
Focus Category:	Water Quality, Water Supply, Education
Descriptors:	
Principal Investigators:	J. Thomas Sims, Maria Pautler

Publications

There are no publications.

Information Transfer Program

The following section describes all Delaware Water Resources Center information transfer activities during FY10, consolidating reporting into a single project **#2010DE197B**. Most activities from the DWRC's FY09 Information Transfer project (**#2009DE200B)** continued into this year.

The FY10 DWRC Information Transfer Activities include:

- Delaware Water Resources Center Electronic Publication WATER NEWS (2000 – 2006 = print; 2007 – present = electronic)
- Delaware Water Resources Center Electronic Newsletter WATER E-NEWS (2002 – present)
- Delaware Water Resources Center Website (3rd edition launched in 2009)
- Delaware Water Resources Center E-group / Courses Link (2002 – present)
- Delaware Water Resources Center Intern Project Poster Session / Advisory Panel Annual Meeting (2001 – present)
- Delaware Statewide Conference Co-sponsor and Participant (2001 – present)

Basic Information:
Delaware Water Resources Center Electronic Publication WATER NEWS

Title:	"WATER NEWS"
Issues during FY10:	Volume 10 Issue 2 (Winter 2009 – Spring 2010) Volume 11 Issue 1 (Summer – Fall 2010)
Description:	Online 8-page newsletter published biannually by the Delaware Water Resources Center
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	Dr. J. Thomas Sims, Director; Maria Pautler, Editor

WATER NEWS is received electronically by over 275 recipients in water-related academic, government, public and private agency, agriculture and industry positions in Delaware and the surrounding area as well as 100 nationwide contacts for water resource issues. It may be accessed via the Delaware Water Resources Center website at: http://ag.udel.edu/dwrc/newsletters.html.

FY10 topics included:

- DWRC Annual Luncheon and Poster Session – April 23, 2010
- Introducing Our 2010-11 Interns
- Spotlight on Undergraduate Internships and Graduate Research
- The UD WATER Project
- DWRC History, Goals, Advisory Panel, Contacts

Basic Information:
Delaware Water Resources Center Electronic Newsletter WATER E-NEWS

Title:	"WATER E-NEWS"
Issues during FY10:	Mar. 2010 Oct. 2010 Feb. 2011
Description:	Brief online "highlights" newsletter published periodically by the Delaware Water Resources Center
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	J. Thomas Sims, Director; Maria Pautler, Editor

WATER E-NEWS is received electronically by over 275 recipients in water-related academic, government, public and private agency, agriculture and industry positions in Delaware and the surrounding area. The current issue and back issues dating to its July 2002 inception may be accessed via the DWRC website at: http://ag.udel.edu/dwrc/newsletters.html.

Featured in each issue of WATER E-NEWS are:

I. News items about the DWRC, including undergraduate internships and graduate fellowships
II. Jobs in Water Resources
III. Upcoming Water Conferences / Events
IV. Water Resources Information / Training

Basic Information: Delaware Water Resources Center Website

Title:	Website: http://ag.udel.edu/dwrc
Start Date:	Third edition; since February 2009
End Date:	Ongoing
Description:	Comprehensive site serving Delaware water resources community
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	Dr. J. Thomas Sims, Director; Maria Pautler, Administrator

The website contains:

- **Delaware Water Resources Center (DWRC) and Director's News:** Latest updates on DWRC activities and information on the DWRC's mission, history, and role in the National Institute of Water Resources (NIWR).
- **Delaware Water Concerns:** Summary of the major areas of concern related to Delaware's ground and surface waters, with links to key organizations and agencies responsible for water quality and quantity.
- **Projects and Publications:** Descriptions of DWRC's undergraduate internship and graduate fellows programs, annual conference proceedings, and project publications dating back to 1993.
- **Advisory Panel:** Purpose, contact information and e-mail links for the DWRC's Advisory Panel.
- **Request for Proposals and Application Forms:** For undergraduate interns, graduate fellowships and other funding opportunities available through the DWRC.
- **Internships and Job Opportunities:** Information on undergraduate and graduate internships from a wide variety of local, regional, and national sources along with current job opportunities in water resource areas.
- **Water Courses and Faculty:** Link to search engine for current list of University of Delaware water resource courses. List of researchers at Delaware universities with an interest in water resources research; also, science and natural resource curricula links.
- **Water Resources Contacts:** Links to local, regional, and national water resource agencies and organizations categorized as government, academia, non-profit, and US Water Resource Centers.
- **Calendar:** Upcoming local, regional, and national water resources events sponsored by the DWRC and other agencies, such as conferences, seminars, meetings, and training opportunities.
- **Newsletters:** Access to DWRC newsletters dating back to 1993.
- **Annual and 5-year Reports:** DWRC annual and 5-year reports, dating to 1993.
- **KIDS' Zone:** Water resources activities and information for kids and teachers.

Basic Information: Delaware Water Resources Center E-group / Courses Link

Title:	Delaware Water Resources Center / Water Resources Agency E-group, originating from the online listing of Delaware water teachers and researchers found on the DWRC website: http://ag.udel.edu/dwrc/faculty_researchers.html
Start Date:	Since December 2001
End Date:	Ongoing
Description:	E-group and link to university water resources courses taught, serving Delaware water resources community
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	J. Thomas Sims, Director; Maria Pautler, Administrator

The online listing of approximately 70 researchers at the University of Delaware, Delaware State University, and Wesley College found on the Delaware Water Resources Center website at http://ag.udel.edu/dwrc/faculty_researchers.html forms the foundation for a broader e-group list maintained by the DWRC reaching additional academic, public, private, and government water community contacts, who are notified via an e-mail newsletter of events and job postings of interest in water resources.

The website also links to a search engine and site for water-related courses currently offered by the researchers.

The total list of e-group members numbered approximately 275 as of February, 2011.

Basic Information:
Delaware Water Resources Center Intern Project Poster Session / Annual Advisory Panel Meeting

Title:	University of Delaware 2011 Undergraduate Research Scholars Poster Session with DWRC Advisory Panel Meeting
Date:	April 22, 2011
Description:	Undergraduate interns presented their 2010-2011 DWRC-funded projects following the annual meeting of the DWRC Advisory Panel
Lead Institute:	University of Delaware Undergraduate Research Program Co-sponsors: Delaware Water Resources Center, Howard Hughes Medical Institute, Northeast Chemical Association, Charles Peter White Fellowship, Chemistry and Biochemistry Alumni Fellowship, Dean's Fund for Transforming Undergraduates: Exploring a Career in Genetics, Milton H. Stetson Memorial Undergraduate Research, McNair Scholars Program, INBRE, College of Agriculture and Natural Resources, Beckman Scholars Program Undergraduate Research, EPSCoR
Principal Investigators:	Lynnette Overby, Director, UD Undergraduate Research Program (overbyl@udel.edu); J. Thomas Sims, Director, DWRC (jtsims@udel.edu)

On April 22, 2011, the undergraduate student interns who had been funded in 2010-2011 by the DWRC, accompanied by their advisors, presented the results of their research at an informal poster session sponsored by the University of Delaware Undergraduate Research Program. Over 100 UD Science and Engineering Scholars joined the DWRC interns to present to a crowd of over 500 visitors. The DWRC Advisory Panel also convened for lunch with the interns and their advisors and then held their annual meeting prior to the poster session. DWRC Director Tom Sims described the Center's plans for 2011-2012 with regard to research funding and public education outreach efforts.

Poster Presentations by 2010-2011 DWRC Undergraduate Interns – April 22, 2011

1) Berry, Kristin. Poster Presentation April 22, 2011. Education and Outreach for the Delaware Wetlands. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

2) Galasso, Aidan. Poster Presentation April 22, 2011. An Analysis of the Impact of Marcellus Shale Development on Water Resources in Pennsylvania. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

3) Hahn, Stephanie. Poster Presentation April 22, 2011. Use of Recycled Water for Irrigation of Turf and Landscape Plants. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

4) Hyatt, Mara. Poster Presentation April 22, 2011. Prevalence of Pathogenic Bacteria in Delmarva Waters from a Virus Point of View. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

5) Lepori-Bui, Michelle. Poster Presentation April 22, 2011. A Watershed Scale Forest Inventory of the Fair Hill Natural Resource Management Area Experimental Watershed in Relation to Precipitation Partitioning. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

6) Miller, Kate. Poster Presentation April 22, 2011. The Impacts of Redefining "Navigable Waters" under the Clean Water Act. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

7) Myers, Kevin. Poster Presentation April 22, 2011. Characterization of Submarine Groundwater Discharge Sites in a Coastal Lagoon. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

8) Porter, Jasmine. Poster Presentation April 22, 2011. Oyster Restoration Efforts at Delaware Inland Bays: Utilizing RIP-RAP as a Substrate for Oysters. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

9) Seetharam, Suneil. Poster Presentation April 22, 2011. Quality of Dissolved Organic Matter in Runoff from Various Watershed Sources. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

10) Simmons, Courtney. Poster Presentation April 22, 2011. The History and Effectiveness of Wetland Mitigation. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

11) Starke, Hannah. Poster Presentation April 22, 2011. Resurfacing Silver Brook Stream and Comparison to Connected Water Bodies. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

12) Yost, Katie. Poster Presentation April 22, 2011. Assessment of Changes in Invertebrate Populations Resulting from Wetland Restoration. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

13) Allen, Melanie. Poster Presentation April 22, 2011. Assessing the Biodiversity of Aquatic Macroinvertebrates Residing in the Cool Run Watershed. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

14) Luxemberg, Melissa. Poster Presentation April 22, 2011. Hydrologic Forecast Modeling of Heterogeneous Land Uses in the Cool Run Watershed. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

15) Binder-Macleod, Rina, Dakota Laidman, and Kim Teoli. Poster Presentation April 22, 2011. Watershed Plan for Cool Run: Funding and Education. 2011. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

Basic Information:
Delaware Statewide Conference Co-sponsor and Participant

Title:	Special Delaware Environmental Institute Dialogue Lecture: "Water in an Uncertain Climate Future"
Date:	November 30, 2010
Description:	Complete article is found in DWRC Summer – Fall 2010 WATER NEWS at http://ag.udel.edu/dwrc/newsletters/Summer10Fall10/WATERNEWSco-Fall2010.pdf , page 4
Lead Institute:	Delaware Environmental Institute Co-sponsors: Delaware Water Resources Center.
Principal Investigators:	Donald Sparks, Director, Delaware Environmental Institute (dlsparks@udel.edu); J. Thomas Sims, Director, DWRC (jtsims@udel.edu)

The DWRC co-sponsored this lecture of the Delaware Environmental Institute Dialogue Series, held on November 30, 2010 at Mitchell Hall on the University of Delaware campus in Newark, Delaware. The notable speaker was Michael P. Totten, chief advisor on climate, water and green technologies at the Center for Environmental Leadership in Business, Conservation International. More than 300 people were in attendance.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	12	0	0	0	12
Masters	0	0	0	0	0
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	14	0	0	0	14

Notable Awards and Achievements

Research Program: The Delaware Water Resources Center (DWRC) has funded fifteen research grant projects during March 2010 through February 2011 that address state water resources priorities identified by the DWRC's Advisory Panel. Two of these projects are graduate fellowships with research focuses on 1)quantifying carbon amount and quality for transport of contaminants in landscapes and 2) microbiome of the eastern oyster. The remaining projects were undergraduate internships researching 1) oyster restoration; 2) use of recycled water for irrigation; 3) education for Delaware wetlands; 4) submarine groundwater discharge; 5) history of wetland mitigation; 6) invertebrate population changes due to wetland restoration; 7) dissolved organic matter in runoff; 8) redefining "navigable waters" under the Clean Water Act; 9) water resources in Pennsylvania; 10) pathogenic bacteria in Delmarva waters with relation to viruses; 11) forest inventory of Fair Hill Natural Resources Management Area; 12) resurfacing Silver Brook Stream; and 13) the UD WATER Project.

Publications from Prior Years

1. 2007DE100B ("Modeling Hydrologic and Geochemical Effects of Land-based Wastewater Disposal") - Other Publications - Akhavan, M., P. Imhoff, and A.S. Andres, 2011, Modeling Hydrologic and Geochemical Effects of Land-based Wastewater Disposal Progress Report, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 16 pages.