Sea Grant Annual Science Symposium "The Shallow Marine Ecosystems of Southern Rhode Island"

Part One: Hydrology, Nutrients, and Bacteria Dynamics

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Sea Grant
Rhode Island

Sea Grant Annual Science Symposium

"The Shallow Marine Ecosystems of Southern Rhode Island"
Part One: Hydrology, Nutrients, and Bacteria Dynamics

This symposium highlights research on Rhode Island's south shore shallow marine ecosystems including Little Narragansett Bay, the Pawcatuck estuary, the salt ponds, and Narrow River. For information on the south shore projects funded by the Rhode Island Sea Grant College Program as part of its Omnibus Proposal for 2001 to 2003, please visit the Rhode Island South Shore Sea Grant Project Web site at http://seagrant.gso.uri.edu/coasts.

The Sea Grant Annual Science Symposium brings researchers and the public together to share information about coastal science of importance to Rhode Island and beyond. Rhode Island Sea Grant is a federal-state partnership that promotes the conservation and sustainable development of marine resources for the public benefit through research, outreach, and education.

Rhode Island Sea Grant College Program
Barry Costa-Pierce
Director

Virginia Lee
Assistant Director
Director of Sustainable Coastal Communities and Environments Extension Program

University of Rhode Island
Narragansett Bay Campus
Narragansett, RI 02882
Tel: (401) 874-6800
Web: http://seagrant.gso.uri.edu

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AGENDA

8:30 Welcome and introduction
Barry Costa-Pierce

8:45 Overview and background of science and management
Virginia Lee

9:15 Nutrient loadings to salt ponds: using watershed indicators to support local management decisions
Lorraine Joubert & Art Gold

9:45 Groundwater nitrate cycling at a densely developed coastal margin: Can we lose the nitrate?
Barbara Nowicki

10:15 Break (Hazard A/B)

10:30 Radium tracers of groundwater supply and water mass residence time in coastal southern Rhode Island
S. Bradley Moran

11:00 Quantifying nutrient export from the Pawcatuck watershed to Little Narragansett Bay
Wally Fulweiler

11:30 Corroboration of a general ecological model in Ninigret and Quonochontaug
James Kremer

12:00 Lunch on your own

1:00 Temperature-nutrient interactions in shallow marine ecosystems: a mesocosm experiment
Scott Nixon

—Continued—

1:30 Indicators of eelgrass health in the south shore salt ponds and a preliminary water quality survey in Little Narragansett Bay
Betty Buckley, Steve Granger & Lora Harris

2:00 Salt Pond Coalition/Watershed Watch monitoring nutrients and bacteria
Vic Dvorak/Elizabeth Herron

2:30 Break (Hazard A/B)

2:40 Fecal coliform total maximum daily load for Green Hill and Ninigret ponds and Factory and Teal brooks
Chris Turner

3:10 Panel discussion of management implications and future research needs

4:00 Adjourn

Nutrient loadings to salt ponds: using watershed indicators to support local management decisions

Lorraine Joubert and Art Gold
URI Cooperative Extension

Background and Goals: The problem of nitrogen loading to the coastal ponds has been studied and debated for the past 30 years. Understanding and quantifying the sources and transformation of nitrogen in coastal landscapes and the ecosystem effects in coastal ponds is driven by the urgent need to protect and restore these valuable resources. Driven by skyrocketing land values that make development of even the most marginal land profitable, developers are pressuring planning and zoning boards to approve new subdivisions and grant exemptions from zoning standards. Although scientists are still working to reduce the uncertainty that plagues mass-balance and dose-response estimates, we are focused on providing timely scientific input and guidance to local and state decision makers. In the spirit of adaptive management, we look forward to working with scientists and decision makers to enable new scientific insights to enrich coastal management.

Situation: In this presentation we review preliminary results of a watershed assessment designed as a decision support tool for these communities. This project is part of the Block Island /Green Hill Pond Wastewater Demonstration Project, one of six national demonstration projects funded by EPA. The goal is to show how individual or "decentralized" septic systems can be managed townwide, with selective use of advanced treatment technologies to control effluent impacts in environmentally sensitive areas. This project is unique among the EPA Demonstration efforts in its focus on nitrogen sensitive coastal waters and is the only project with a strong link to university research and outreach through URI Cooperative Extension and Rhode Island Sea Grant. Most importantly, it is the sole case where local communities are taking the lead using a watershed approach.

Approach: The updated CRMC Salt Pond Management Plan and URI MANAGE nutrient loading estimates point to septic systems as a major source of nitrogen to the ponds, constituting almost 80 percent of total source load to the groundwater in some watersheds. Given the uncertainties surrounding both nitrogen watershed sinks and the loading-response relationships of the coastal pond ecosystems, we use a number of risk indices to evaluate "cumulative" water quality risks at the watershed level. These indices couple high-quality spatial data on a suite of landscape attributes with our current understanding of land uses to evaluate and compare risks to the ponds. Our indices include percent impervious cover, extent of degraded riparian cover, and nitrate loading to groundwater in coastal watersheds. A variety of land use scenarios are tested, including future development and comparison with historical levels. The study area includes the South Shore ponds, with a focus on Green Hill and eastern Ninigret Ponds. Initial findings suggest that a combination of management practices, including use of denitrifying technologies, stormwater controls, and wetland riparian protection are needed to minimize water quality degradation.

Progress: All three towns have already adopted landmark ordinances that mandate regular septic system inspection and maintenance, repair of failures, and in the case of Block Island and South Kingstown, phase-out of all cesspools by 2005 and 2013, respectively. South Kingstown and Charlestown have agreed to develop zoning performance standards to better control the effects of onsite wastewater discharges to the coastal ponds and groundwater drinking water supplies. The current assessment will help establish legally and technically sound guidelines for appropriate use of advanced technologies to help protect and restore the coastal ponds, guidelines that can be adapted as more definitive studies link pollution sources to impacts in the ponds.

Groundwater nitrate cycling at a densely developed coastal margin: Can we lose the nitrate?

Barbara Nowicki
URI Graduate School of Oceanography

Recent work at freshwater stream and wetland margins has shown that riparian zones can be important sites for nitrate removal from inflowing groundwater. Nitrate loss occurs through the process of bacterial denitrification where nitrate (NO_3) is reduced to dissolved nitrogen gas (N_2), and subsequently lost to the atmosphere. Denitrification can result in significant losses of NO_3 from groundwater, and groundwater traversing riparian zones encounters conditions of low oxygen and high dissolved organic carbon most favorable to denitrification. We have hypothesized that estuarine margins may also be sites where groundwater passes through soils and sediments conducive to active nitrate reduction, and we are currently involved in ongoing work to better understand nitrogen and carbon dynamics in coastal groundwater. Of particular interest is the effect of nearshore processing on the fate and delivery of groundwater-derived NO_3 to estuaries.

In this study, groundwater flowing through a densely developed coastal area adjacent to Green Hill Pond was sampled monthly from March through November. Fresh groundwater was taken from the estuarine shoreline (well depth = 1 m), from surface water streams and seeps across the beach, and from subtidal discharge through sediments beneath the estuary itself. Groundwater denitrification was measured in-situ using dissolved N_2 gas production and N_2/Ar ratios as indicators of NO_3 reduction.

Preliminary results suggest that groundwater entered the estuary at a rate of approximately 0.85 m^3/d over a 170 m length of shoreline. NO_3 concentrations ranged from 0-400 mm/l (5.6 mg/l) and often exceeded NO_3 concentrations in the adjoining estuary by as much as 100-fold. Highest concentrations were found in surface seeps across the beach, and in the estuarine sediments at 20 cm. Groundwater discharging sub-tidally to Green Hill Pond contained high concentrations of NO_3 (approx. 200-300 mm/l; 2.8-4.2 mg/l). Groundwater NO_3 concentrations were inversely correlated with both the width of the natural buffer zone, and the distance of the groundwater well to the nearest house. Minimum groundwater O_2 concentrations occurred in August, corresponding with maximum groundwater temperatures. Groundwater denitrification displayed a seasonal cycle and was linearly correlated with temperature.

At this study site, most NO_3 removal from groundwater apparently occurred upstream of the estuarine shoreline and may be related to the degree of oxygenation or reduction of the surrounding soils. Little if any additional removal was observed in passage through the estuarine sediments. Preliminary results suggest that the coastal interface may be a zone of convergence for several different groundwater sources.

Radium tracers of groundwater supply and water mass residence time in coastal southern Rhode Island

S. Bradley Moran
URI Graduate School of Oceanography

The complexity of coastal ecosystems provides a significant challenge to scientists and managers who seek to assess their response to pollutant inputs or environmental change. Submarine groundwater input represents a significant, though poorly constrained, source of dissolved nutrients and contaminants to coastal watersheds. Naturally occurring Ra isotopes, ^{224}Ra ($t_{1/2}$ = 3.6 d), ^{223}Ra ($t_{1/2}$ = 11.4 d), ^{228}Ra ($t_{1/2}$ = 5.8 y) and ^{226}Ra ($t_{1/2}$ = 1600 y), are promising groundwater tracers, due to their relatively high activity in coastal aquifers that leads to their enrichment, via submarine groundwater transport, in salt marshes and adjacent shelf waters. The differing half-lives of these tracers provides information on both annual times-scales (^{228}Ra, ^{226}Ra) and short-term "event driven" temporal variations (^{223}Ra, ^{224}Ra) in submarine groundwater transport.

Measurements of Ra isotopes have been made to quantify seasonal changes in submarine groundwater supply and water mass residence times in coastal southern Rhode Island. In the Pettaquamscutt River estuary, the Ra-based seasonal groundwater flux (1.5-22 L m^{-2} d^{-1}) brackets values previously reported for this system and other local coastal ponds. These results are consistent with estimates of aquifer recharge over an annual cycle determined using a tidal prism model and a Ra-based estuarine residence time of 8 $\pm$ 4 d. Based on these groundwater fluxes and groundwater nutrient concentrations, the input of inorganic nitrogen and phosphorus from groundwater to the Pettaquamscutt ranges from 61-

180 mmol m^{-2} y^{-1} and 4.4-13 mmol L m^{-2} y^{-1}, respectively. Preliminary results from ongoing studies in Potter, Green Hill, Point Judith, Ninigret, Quonochontaug, and Winnapaug Ponds will also be presented.

Quantifying nutrient export from the Pawcatuck watershed to Little Narragansett Bay

Wally Fulweiler
URI Graduate School of Oceanography

The Pawcatuck River is the largest source of freshwater to Little Narragansett Bay. In order to quantify the delivery of organic carbon, sediments, and nutrients (nitrogen, phosphorus, silicate) associated with this flux of river water, we obtained concentration measurements on approximately 100 occasions between December 2001 and November 2002. Water samples were collected at the Stillman dam—the last dam before tidal waters—on the Pawcatuck River. Our sampling site was chosen to correspond with that used by the United States Geological Survey (USGS) which has been recording continuous water discharge data since 1940. The USGS also obtained water quality data, at varying intervals (monthly, bimonthly and quarterly), at this station from 1976 to the present. The long-term USGS nutrient flux data will be compared with our more recent samples to document changes in the nutrient flux from the watershed to the estuary.

Corroboration of a general ecological model in Ninigret and Quonochontaug

James Kremer
Department of Marine Sciences, University of Connecticut Avery Point Campus

A model of estuarine responses to nitrogen loading has been developed to assist with planning and land-use management decisions. It is an empirically based numerical simulation linking land-use and N-loading to ecologically important and socially relevant endpoints of water quality, hypoxia, and eelgrass habitat.

Developed initially for Waquoit Bay (Cape Cod, Mass.), we have applied it to two Rhode Island coastal ponds, as well as to six new sites, in Buzzards Bay, Mass. The only changes were site-specific descriptions of bathymetry, and forcing functions; all ecological parameters were unchanged. Simulations were compared to recent field data from all sites, and results were evaluated for chlorophyll stock, phytoplankton primary production, planktonic net community production and respiration, DIN, DIP, water clarity, macroalgae stock, and total system net P and R. The CLUE model (Changing Land Use and Estuaries) simulates the overall patterns of ecologically important variables related to the eutrophication in a range of shallow coastal sites. It is general, dynamic, and predictive. Process-based simulations often require site-specific "tuning," yet our unchanged general model still achieves enough generality for use across a wide range of sites.

Temperature-nutrient interactions in shallow marine ecosystems: a mesocosm experiment

Scott Nixon
URI Graduate School of Oceanography

We investigated the independent and interactive effects of nutrient loading and summer water temperature on phytoplankton, drift macroalgae, and eelgrass (*Zostera marina*) in a coastal lagoon mesocosm experiment conducted from May through August, 1999. Temperature treatments consisted of duplicate controls that approximated the 9-year mean daily temperatures for Ninigret and Point Judith lagoons and duplicate treatments approximately 4°C above and 4°C below the controls. Nutrient treatments consisted of the addition of 6 mmol N m^{-2} d^{-1} and 0.5 mmol P m^{-2} d^{-1} to duplicate mesocosms 4°C above and 4°C below the 9-year daily mean. Nutrient enrichment produced marked phytoplankton blooms in both cool and warmed treatments during early summer. These were replaced after mid-summer by dramatic growths of macroalgal mats of *Enteromorpha flexuosa* and, to a lesser degree, *Cladophora sericea*. No phytoplankton blooms were observed in the cool unenriched treatments, but blooms did develop in the mean temperature and warmed mesocosms during the second half of the summer that were similar in intensity, though of shorter duration, than those observed earlier in the enriched systems. Macroalgal blooms did not occur in the unenriched mesocosms. Sustained warm water temperatures markedly decreased eelgrass density and below ground production and increased the time interval between the initiation of new leaves, particularly when the biomass of macroalgae was high. The negative impact of elevated water temperature on eelgrass was significantly increased under conditions of elevated inorganic nutrient input. By the end of summer, virtually all of the measures of eelgrass health declined in rank order from cool, to mean, to cool enriched, to warm, to warm enriched treatments. It is likely that the marked declines in eelgrass abundance observed during recent decades in the northeast have resulted from an unfortunate interaction of increasing nutrient enrichment combined with increasing summer water temperatures.

Indicators of eelgrass health in the south shore salt ponds and a preliminary water quality survey in Little Narragansett Bay

Betty Buckley, Steve Granger, and Lora Harris
URI Graduate School of Oceanography

The results of many summers of mesocosm experiments with living models of the salt ponds have led us to develop a set of indicators of health for eelgrass, *Zostera marina*, as it responds to nutrient loading and light and temperature stress. The indicators include shoot density, lateral shoot production, plastochrone interval, ratio of new shoot to new root and rhizome production, leaf length, and possibly several other characteristics. In this presentation we will attempt to correlate these measures of plant health from eelgrass sampled in each of the south shore salt ponds with estimates of anthropogenic nitrogen loading to the relevant salt pond watershed calculated by the MANAGE model. We will also present the results of two summers of water quality surveys from seven stations in Little Narragansett Bay, including near-surface and near-bottom sampling for temperature, salinity, dissolved inorganic nutrients, water column chlorophyll a, and dissolved oxygen.

Salt Pond Coalition/Watershed Watch monitoring nutrients and bacteria

Vic Dvorak, Salt Ponds Coalition, and Elizabeth Herron, URI Cooperative Extension/Watershed Watch

In 1985 Virginia Lee of the Rhode Island Sea Grant/URI Coastal Resources Center set up Pond Watchers, the first volunteer water quality monitoring program in New England. Rhode Island Sea Grant provided funding with the assistance of the Shelter Harbor Conservation Society. Water samples were taken to evaluate bacterial counts, nitrates, chlorophyll, and dissolved oxygen. Also noted were the temperature, tides, wind direction and strength, whether it had rained recently, and the clarity of the water. Pond Watcher data has forced local change, such as the closure of Green Hill Pond to shell fishing and the installation of more effective septic systems to replace those that previously were polluting the pond. The Pond Watcher program has also established a study lasting 18 years concerning the health of salt pond waters.

Today, the bacterial testing is still going strong on almost all the ponds in South County. In 1993 the Shelter Harbor Conservation Society passed sponsorship along to the Salt Ponds Coalition, which has since been responsible for raising money from the community to support this very important endeavor. Water quality monitoring results for 2002 will be presented and compared to the previous five years.

Following a trial run in 2000 to review protocols and scheduling issues, the URI Watershed Watch program initiated more comprehensive monitoring of Green Hill and Ninigret ponds with the Salt Pond Watchers in 2001. Funded under an EPA Wastewater Management Demonstration Grant, the objective of this monitoring is to track water quality trends in surface and ground waters, and provide results of this monitoring and related local research in an accessible format to local decision makers and the general public. A secondary objective is to compare the multiple tube fermentation (MPN) method, which the Salt Pond Watchers use, with direct filtration onto mTEC, the easier method that URI Watershed Watch relies on for assessment of fecal coliform levels. Both methods are

EPA approved. Preliminary results from the 2001 and 2002 seasons will be presented.

Fecal coliform total maximum daily load for Green Hill and Ninigret ponds and Factory and Teal brooks

Chris Turner
Rhode Island Department of Environmental Management

DEM is conducting a total maximum daily load (TMDL) study that addresses fecal coliform impairments to Green Hill Pond, two of its tributaries Factory Brook and Teal Brook, and a portion of Ninigret Pond. These four water bodies have been listed on Rhode Island's 1998 and 2000 303(d) Lists of Impaired Waters. Section 303(d) of the federal Clean Water Act requires that a water quality restoration plan, known as a TMDL be completed. The goal of this TMDL is to set bacterial loading reduction targets so that all designated uses, including shellfish harvesting and swimming, are attained and maintained. The TMDL has four basic elements. The first three include characterizing existing conditions in the water bodies, identifying fecal coliform sources, and determining the reductions in loadings needed to meet standards. The TMDL will finally specify actions needed to restore water quality and the designated uses of each water body.

DEM staff conducted water quality surveys in the study area between 1999 and 2001, sampling during twelve dry weather days and one wet-weather day. Most water body segments in the watershed were found to violate either one or both parts of the state's fecal coliform standard during both dry and wet weather. The reductions in concentration needed to bring all segments in the watershed into compliance range between 23 and 99 percent.

No dry weather sources of fecal coliform bacteria other than those that would occur naturally in forested wetland and swamp systems could be identified in the watershed, therefore, no best management practices (BMPs) could be recommended to address elevated dry weather bacteria concentrations.

The DEM wet-weather sampling pointed to storm water runoff as the cause of wet weather elevations. The increased bacterial concentrations are thought to result from the washoff of fecal material that accumulates on surfaces in the watershed during intervening dry periods. Major sources of fecal coliform in the stormwater are most likely the feces of domestic animals, wildlife, and waterfowl.

Historic studies of the area have concluded that substandard or failing septic systems are another significant source of fecal coliform bacteria. A majority of the area surrounding the pond is high-density residential development on septic systems or cesspools. Many areas adjacent to the pond have a high-density residential use, where septic systems or cesspools are used for waste disposal. The population of the area increases significantly during the summer months. A 1994 survey of septic systems in the area also found a 13 percent failure rate for systems in the densely developed area.

To identify the sources, DEM initiated a bacterial source tracking study of the area. The approach involved comparing the genetic characteristics of *E. coli* bacteria in the feces of host species in the watershed to those of bacteria in the waters of Green Hill Pond. During the summer and early fall of 2002, DEM staff collected 61 scat samples representing mute swan, Canada goose, gull, mallard duck, rabbit, otter, raccoon, deer, dog, and horse. Nine septic tanks were also sampled.

On the same days that DEM collected scat samples, surface water "unknown" samples were collected from the pond and its tributaries. Five surveys were conducted during dry weather where scat and water samples were collected at the same time. DEM also collected water samples from Green Hill Pond, its tributary streams, and a storm drain during two wet weather surveys. All samples were first evaluated for their fecal coliform content (fc/100g or fc/100ml) by a local laboratory, which then identified *E. coli* colonies on the sample plates. The characterization of *E. coli* strains in scat and water samples is presently being performed by Dr. Hemant Chikarmane at Cape Cod Community College using the polymerase chain reaction method. DEM presently expects that this characterization will be completed in early 2003.

Because storm runoff has a significant adverse impact on the streams and ponds, the TMDL will recommend a combination of structural and non-structural BMPs for controlling storm water runoff at several locations within the watershed. Reductions in the amount of fecal coliform bacteria buildup during dry weather conditions can be achieved through enforcement of a pet waste ordinance and street sweeping during the critical summer season. Ongoing efforts to improve septic system maintenance and to replace sub-standard systems through the recently adopted waste-water management districts are encouraged.