Papers on the Management of Urban and Rural Coastal Ecosystems

Scientific Research in the Providence River, Upper Narragansett Bay and Tributaries

ELLEN SUCHOW FORMAN

September 1983

COASTAL RESOURCES CENTER

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INTRODUCTION

ACRONYMS USED

CRC	-	Coastal Resources Center
DOE	-	Department of Energy
EPA	-	Environmental Protection Agency
GSO	-	Graduate School of Oceanography, University of R.I.
MERL	-	Marine Ecosystems Research Laboratory
NAS	-	National Academy of Sciences
NMFS	-	National Marine Fisheries Service
NOAA	-	National Oceanic & Atmospheric Administration
OCZM	-	Office of Coastal Zone Management
R.I. DEM	-	Rhode Island Department of Environmental Management
URI	-	University of Rhode Island
USGS	-	United States Geological Survey

INTRODUCTION

This is a summary of ongoing research and monitoring activities in Upper Narragansett Bay. Its purpose is to identify information which can be synthesized to assist in management decisions on Upper Narragansett Bay. The activities currently or soon to be in progress represent approximately 3 million dollars in research. The projects encompass a broad range of disciplines--fisheries biology, physiology, population ecology, estuarine hydrodynamics, computer modeling, marine geochemistry, nutrient dynamics, and decision techniques--and are directed by investigators from academic, government and private institutions. The overlapping interests of investigators suggests the need for a conscious, coordinated Upper Bay research planning effort. The concurrence of scientists and government managers on research goals must be reached in order to provide pertinent information on water quality status and control options. This research summary can provide a common information base and point of departure for cooperative research planning efforts between scientists and regulators.

EFFECTS OF POLLUTION ON AQUATIC ORGANISMS

1. COASTAL ENVIRONMENTAL ASSESSMENT STATIONS (CEAS) PROGRAM

Donald Phelps EPA, Narragansett

1982-ongoing $5,000 annual funding

Objectives

1) To determine the physiological condition (scope for growth) and metallothionein and glutathione levels in the tissues of mussels caged along a pollution gradient in Narragansett Bay. 2) To relate the changes in these parameters to the degree of environmental contamination, as measured in the water column and in the animal tissues.

Project Description

This project is part of the Coastal Environmental Assessment Stations (CEAS) program, which was established to assess the relative environmental condition of marine coastal systems through the use of a biological indicator, the blue mussel (*Mytilus edulis*). The CEAS approach has been instrumental in identifying pollutant levels in tissues of mussels sampled in estuaries and embayments.

At the initiation of the CEAS program in 1976, metal and organic residues were measured in mussel tissues. In 1979, a laboratory program was added, which compared physiological responses between field-exposed animals determined to have high and low tissue residue levels of materials such as heavy metals and total petroleum hydrocarbons.

In 1982, a project was initiated, which is in progress, to test physiological responses of caged mussels, in terms of scope for growth, and metallothionein and glutathione tissue levels. Scope for growth is an index of the energy available to individual animals for growth and reproduction. Metallothionein and glutathione are involved in the detoxification of metals and organics in mussel tissue. In this study caged mussels collected near Jamestown were placed at a site in the upper bay (near Conimicut Point) and in the lower bay (near Jamestown) in the spring of 1982. Two consecutive monthly samples of 10 mussels at each station were collected and tested at EPA, Narragansett for scope for growth. Thirty animals from each site were also sent to a California laboratory for analyses of metallothionein and glutathione levels in the tissues. The results will be correlated with historical data on levels of metals and organics in the water column and in mussel tissues from these sites. The results of this study should indicate whether the ability of the mussels to adapt to high levels of metals in the environment, through metallothionein and glutathione production, has been exceeded or impaired.

2. THE EFFECTS OF ENVIRONMENTAL CONDITIONS ON THE ENERGETICS AND REPRODUCTION OF MYTILUS EDULIS FROM NARRAGANSETT BAY

William Nelson EPA, Narragansett

1982-1984 Funding by GSO

Objectives

To measure the physiological responses (scope for growth) and reproductive outputs of indigenous populations of mussels along a pollution gradient in Narragansett Bay.

Project Description

Ten animals, comprising a range of size classes representative of the natural population, are sampled at 2-4 week intervals at each of two bay stations. The stations are located along a diminishing pollution gradient: 1) north of Prudence Island, near the northernmost boundary of the stable Bay mussel population and 2) west of Jamestown just below Dutch Island. Scope for growth is an index of the energy available to individual animals for growth and reproduction. This physiological parameter is measured at EPA, Narragansett under conditions similar to those encountered in the field. A goal of the study is to generate allometric equations which can predict the scope for growth for any sized animal, under various environmental conditions. By correlating the physiological index, scope for growth, with the reproductive output of the animal (as measured by fecundity, caloric content of the eggs, and larval survival during spawning periods) and environmental parameters (such as salinity, temperature, total suspended particulates and percent particuate organics) the effects of environmental conditions on physiological population dynamics may become evident.

3. EXAMINING THE POPULATION DYNAMICS OF THE MUSSEL MYTILUS EDULIS ALONG A POLLUTION GRADIENT

Cliff Katz (Research Fellow) and Donald Phelps EPA Narragansett

March 1983-February 1985 $46,000 total funding by NAS

Objective

To compare population dynamics of mussels caged along a pollution gradient in Narragansett Bay.

Project Description

The focus of this study is to predict the effects of environmental perturbations on the population dynamics of the indigenous blue mussel, Mytilis edulis. The impact of inorganic and organic toxicants (e.g., metals, hydrocarbons, PCB's) and seasonal variations in abiotic factors

(e.g., dissolved oxygen, salinity, temperature) is being examined in relation to three population parameters: growth, survivorship, and fecundity. Long-term dynamics, stable population structure, and sensitivity of several mussel size classes to toxicants will be generated from these parameters using linear matrix models. The experimental design consists of transplanting mussels from a relatively clean area in Narragansett Bay to four sample sites. These sites are located along a diminishing pollution gradient at 1) Conimicut Point, 2) Ohio Ledge, 3) Conanicut Point, and 4) the EPA Environmental Research Laboratory, Narragansett. Sampling of the replicate mussel populations, beginning in June 1983, is to occur at four-month intervals.

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4. ANALYTICAL CHEMICAL SUPPORT FOR STUDIES ON THE FATE AND EFFECTS OF TOXIC ORGANIC COMPOUNDS IN THE MARINE ENVIRONMENT BY THE ENVIRONMENTAL RESEARCH LABORATORY, NARRAGANSETT

James Quinn and Richard Pruell GSO Al Beck EPA, Narragansett
October 1980-December 1983 $50,000 annual funding by URI/EPA

Objective

To examine the uptake and depuration of PCB's and polynuclear aromatic hydrocarbons (PAH's) by mussels (Mytilus edulis) exposed to resuspended Providence River sediments in the laboratory.

Project Description

Mussels collected from unpolluted coastal waters were exposed for forty days in laboratory tanks at EPA, Narragansett, to resuspended Providence River sediments collected at the mouth of the Pawtuxet River in the summer of 1982. A control group of mussels was exposed to clean bay water without sediment. During this exposure period, water, sediments, and mussel tissues were analyzed at intervals for PCB's and PAH's. After forty days, the tanks were replaced with clean bay water and the measurements repeated to examine changes during depuration. These analyses are in progress.

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5. A BIOGEOCHEMICAL SURVEY: COPPER AND NICKEL IN MERCENARIA MERCENARIA, RELATIVE TO CONCENTRATIONS IN THE WATER COLUMN IN A NEW ENGLAND ESTUARY

Douglas Cullen GSO Graduate Student
1978-1983 Funding by EPA

Objective

To establish a quantitative relationship between the water column distribution of dissolved and particulate copper and nickel, and the concentration of each metal in tissue samples of M. mercenaria collected from Narragansett Bay, Rhode Island.

Project Description

Between nine and fourteen specimens were analyzed from nine sites within Narragansett Bay, and two tissue components of each specimen, the whole tissue less kidney (WTLK) and kidney concretions, were analyzed separately and individually for copper and nickel. Water column samples (surface and bottom) of dissolved and particulate copper and nickel were collected across the salinity gradient in Narragansett Bay. The concentrations of copper and nickel found in each tissue component were compared to dissolved and particulate concentrations of each metal found in the water column. The relationships between the metals in tissues and in the water column were explored as a means of estimating water column concentrations from M. mercenaria tissue samples.

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6. UPPER NARRAGANSETT BAY FISHERIES HABITAT

Richard Crawford CRC

July 1982-June 1985 $62,239 total funding by Sea Grant

Objectives

1) To compare growth rate and development as derived from direct observation and from RNA/DNA ratios of winter flounder from laboratory hatched eggs collected from unpolluted Charlestown Pond and the polluted Providence River to provide resource managers with an assessment of the potential impacts of water quality on an important finfish resource. 2) To examine literature on Upper Narragansett Bay water quality, sediment quality, and hydrodynamics in relation to what is known about the distribution and biology of the quahog resources in order to help define research goals for enhanced fisheries and water quality management.

Project Description

During 1982, a field survey was conducted for prospective winter flounder spawning sites in the Providence River and Charlestown Pond. Two promising sites were located in each area, and alternative sites were identified in the event the primary sites were not productive. Thermographs were placed near one primary site in each area to record the temperature in these locations throughout the winter and early spring. In Spring 1983, in the absence of winter flounder eggs from field sites, adults were collected from clean and polluted sites, and the eggs were stripped, fertilized and hatched in tanks at the EPA Narragansett Laboratory and the Marine Ecosystems Research Laboratory (MERL). Preliminary data on prolarval growth rates will be forthcoming from the calculation of RNA/DNA ratios. In 1984, the work will be repeated using eggs collected from clean and polluted sediments, and embryonic development and larval growth in MERL tanks will be measured over a longer period of time.

7. A STUDY OF FATTY ACID PATTERNS IN ZOOPLANKTON IN NARRAGANSETT BAY AND RHODE ISLAND SOUND

Perry Jeffries GSO

1978-1985 (summers) $60,000 annual funding by DOE

Objective

To relate fatty acid patterns in zooplankton to ecological patterns to estimate seasonal changes, stabilities, and the well-being of the community.

Project Description

Fatty acids in zooplankton from Narragansett Bay and Rhode Island Sound are measured in a downbay transect at the following stations: 1) near Sabin Point, 2) off Rocky Point, 3) Fox Island, 4) Whale Rock, 5) between Block Island and Whale Rock, and 6) off Block Island. Zooplankton sampling is performed every 3 to 4 weeks with a 1/2 meter #6 mesh net. The fatty acid patterns in Narragansett Bay and Rhode Island Sound will be compared to those from Massachusetts Bay and the New York Bight.

FISHERIES BIOLOGY

1. PRELIMINARY MARINE BIOLOGICAL SURVEY - NARRAGANSETT BAY ESTUARINE SANCTUARY

Richard Satchwill Division of Fish and Wildlife, R.I. DEM

October 1982-December 1983 $45,000 total funding by OCZM and State match

Objective

To inventory animals, bottom characteristics and water chemistry parameters in the waters of the Narragansett Bay Estuarine Sanctuaries in order to provide a baseline assessment for a long-term monitoring program.

Project Description

The estuarine sanctuaries in Narragansett Bay include North Prudence Island, Patience Island and Hope Island. The survey will produce data on sediment characteristics (grain size), shellfish species composition and abundance, and water chemistry (salinity and water temperature) on a daily basis. Sediments and shellfish are randomly sampled from within one square meter quadrats. Beach seines are used for juvenile finfish sampling and fyke nets for collecting adults. Water chemistry parameters are measured at eight permanent stations in the sanctuary waters to provide a single depth-averaged value for each station.

2. COASTAL FISHERY RESOURCE ASSESSMENT

Timothy R. Lynch Division of Fish and Wildlife, R.I. DEM

April 1979-October 1984 $170,400 total funding by NMFS

Objectives

1) To detect changes in diversity and abundance of major finfish species in Narragansett Bay. 2) To predict the future availability of the R.I. fishery through Narragansett Bay catch data.

Project Description

The bay has been divided into a 1/4 square nautical mile grid system. The stations are randomly sampled from two depth strata (0'-20' and >20') in the spring and fall by a single 20 minute tow. The weights, lengths, and density per square meter of the finfish are recorded for each tow. A 42' Western rig dragger, towing a U.R.I. 340 high rise net (3/4 scale) fitted with a 1/4" (1/2" stretch) mesh liner was used.

PHYSICAL, CHEMICAL AND GEOLOGICAL PROCESSES

1. PROVIDENCE RIVER POLLUTANT TRANSPORT DYNAMICS

Frank White and Malcolm Spaulding Dept. of Ocean Engineering, URI

July 1981-June 1984 $125,500 total funding by Sea Grant

Objectives

Measurements of current (two horizontal components), surface elevation, salinity and temperature will be made to determine the transport of water mass and salt due to tides, winds, density differences, and non-local forcing mechanisms.

Project Description

Since mid-1981, hydrodynamic field data have been collected and evaluated to calibrate and refine a three-dimensional hydrodynamic model for predicting pollutant transport in the Providence River and Upper Narragansett Bay. Data have been collected seasonally in the Providence River to provide long-term profiles of current speed and direction, temperature, salinity, tidal height, and wind speed and direction. Tide gauges, four current meters and a salinity/temperature gauge were deployed in surface and bottom waters in a horizontal transect across the Providence River, from Gaspee Point to Bullocks Cove, to provide continuous records over 2 1/2 months. Additional data on currents, tides and wind will be collected at a mid-depth in the the water column through June 1984 at the following sites along a longitudinal transect: the mouth of the Pawtuxet River, Gaspee Point and at a site north of Conimicut Point. The impacts of low frequency currents and increased freshwater flow during storm conditions on bay hydrodynamics will also be investigated.

2. ESTIMATES OF COMBINED SEWAGE AND STORM WATER FLOWS FROM THE CITY OF PROVIDENCE

Brooks Martin and Donald Robadue, Jr. CRC, URI

February 1982-January 1983 $5,000 funding by GSO and Sea Grant

Objective

To predict the total volume of runoff and sewage that flows to the Fields Point plant and into Upper Narragansett Bay following a given rain event.

Project Description

A level II computer simulation model of the Providence sewage system has

been developed. The model generates hourly flow estimates for the Fields Point sewage treatment plant, combined sewer overflows and storm drains, when rainfall rates are provided. This knowledge can be used to estimate the contributions of combined sewer systems to the Bay. When calibrated and verified, the model could serve as an effective facility planning tool for ranking individual sewerage system basins and outfalls in terms of priority for study.

3. MATHEMATICAL PREDICTIONS OF DISSOLVED COPPER CONCENTRATIONS IN THE PROVIDENCE RIVER AND UPPER BAY

Brooks Martin and Donald Robadue, Jr. CRC, URI

Part of project, 'Water Quality Management in Urban Estuaries' (see Decision Techniques section)

Objective

To develop a mathematical model to predict dissolved copper concentrations in the Providence River and Upper Bay.

Project Description

The model developed is a modified version of the one-dimensional model of Fischer and coworkers.[1] The modifications allow the model to manipulate multiple inputs of copper (from sewage treatment plants) and consider the nonconservative aspects of copper behavior (processes that affect concentration besides dilution). The mathematical simulation takes data on the copper concentrations in sewage effluents and the Blackstone and Pawtuxet Rivers and generates a graph of predicted dissolved copper concentrations in the Providence River and Upper Bay. After satisfactory agreement between model predictions and field data (collected by MERL, 1980), the model was used to examine 1) the effect of river flow on copper distribution and 2) various sewage treatment scenarios.

[1] Fischer, H.B., J. Imberger, C.J. List, R.C.T. Koh, and N.H. Brooks. 1979. Chapter 7 In: Mixing in Inland and Coastal Waters. Academic Press, New York, pp. 263-269.

4. DISSOLVED OXYGEN DYNAMICS AND THE ASSIMILATIVE CAPACITY OF AN URBAN ESTUARY

Scott Nixon, Barbara Nowicki, and Candace Oviatt GSO

July 1982-1984 $130,000 annual funding by Sea Grant

Objectives

1) To evaluate the relative importance of organic matter and nutrient inputs to the lowering of oxygen levels in the Providence River. 2) To identify the major sources of input, including sewage treatment plants, storm runoff, upstream inputs, and estuarine circulation patterns in the Providence River. 3) To develop an oxygen budget for the Providence River.

Project Description

In the first year (September 1982 - September 1983), a series of seasonal surveys were conducted of the vertical distributions of oxygen, temperature and salinity at twenty stations--from the mouth of the Providence River up to the falls of the Blackstone River. These data are being used to : 1) identify chronic problem spots by estimating the volume and area of the estuary on a particular day which experience low oxygen problems; 2) develop a seasonal picture of the oxygen conditions in the upper reaches of the estuary; 3) verify oxygen budgets and simulations which are being developed through this project.

Biweekly samplings of the effluents of the sewage treatment plants (Fields Point, Riverside and Bucklin Point) and tributary rivers (Blackstone, Pawtuxet, Moshassuck and Woonasquatucket) will be conducted over a one year period (Fall 1982-1983). Water samples will be analyzed for dissolved oxygen, temperature, salinity, ammonia, particulate carbon, nitrogen and phosphorous, nitrate-nitrite, phosphate, dissolved organic carbon, and the 5-day biological oxygen demand (BOD_5). The sewage treatment plants and various combined sewer overflows (CSO's) will also be sampled during storms to estimate the magnitude of organic slug loadings during these events. In addition, three tide gauges have been deployed--at Conimicut Point, at the Gulf Oil Dock at Fields Point, and in the Seekonk River--to estimate the volumes of Narragansett Bay water entering the Providence River under various conditions of winds and tides.

An automatic water sampler was deployed throughout the summer of 1983 at Conimicut Point, the Gulf Oil Dock and the Seekonk River in order to evaluate the Upper Bay boundary conditions and the relative contribution of tributary rivers and open bay waters to this region. The sampler will provide continuous measurements (every 10 minutes) of dissolved oxygen, temperature, salinity, and fluorescence at four depths, over four to five day periods. The data collected in this study will provide estimates of the fluxes of these parameters in Upper Bay waters. In addition, *in vivo* fluorescence measurements at this site will provide indirect means of estimating the chlorophyll *a* content of the water. Sampling will proceed for approximately one month at each of three sites in the following sequence: 1) Conimicut Point, 2) Seekonk River, and 3) Gulf Oil docks at Fields Point.

Experiments to examine the impacts of dilution and physical processes of the River on BOD_5 will be initiated in 1983. In addition, the oxygen dynamics in the Providence River will be studied through measures of primary productivity down bay, and oxygen fluxes from the benthos and at the air-sea interchange.

5. POLLUTION HISTORY OF THE PROVIDENCE RIVER AND THE SEEKONK RIVER

Suzanne Bricker Urso GSO Graduate Student
September 1982-ongoing $750 total funding by URI Alumni Fund, Exxon Fund and Sigma Xi grant

Objective

To construct temporal and spatial pictures of heavy metal pollution in Narragansett Bay.

Project Description

Sediment cores were obtained with a stainless steel corer from five marshes in a transect from the Seekonk River to lower Narragansett Bay. Analyses are in progress for the active fraction of a number of heavy metals (Ag, Pb, Fe, Cd, Cr, Zn, Cu, Ni, Mn) in the sediment samples. A final report will be available by February 1984.

6. HYDROCARBONS AND OTHER POLLUTANTS IN URBAN RUNOFF AND COMBINED SEWER OVERFLOWS: CHARACTERIZATION AND IMPACT ON NARRAGANSETT BAY

Eva Hoffman and James Quinn GSO
$300,000+ total funding by NOAA

Overall Objective

To study the problem of urban runoff in the Upper Narragansett Bay watershed.

Objective of Task #1

To compile an annual petroleum hydrocarbon and metal pollution budget for Narragansett Bay, from urban runoff loadings.

Project Description

The loadings of petroleum hydrocarbons, polyclyclic aromatic hydrocarbons and metals were calculated for each land use, for cities and towns, and for watersheds of Upper Narragansett Bay. Mean loading factors for petroleum hydrocarbons and individual polynuclear aromatic hydrocarbons were calculated from analyses of runoff samples collected at four land uses and from historical rainfall records. Similar loading factors for heavy metals were calculated based on the field data of Hunt and Latimer. These annual loading rates were combined with local land use data to estimate annual loading rates to basins and sub-basins of Upper Narragansett Bay. These data are summarized in a March 1983 report to the Rhode Island Department of Environmental Management.

Objective of Task #2

To estimate the contributions of metals and hydrocarbons from the Fields Point sewage treatment plant to the Providence River, under a variety of environmental conditions.

Project Description

In 1982, the effluent and influent of the Fields Point sewage treatment plant were sampled after three storm events for petroleum hydrocarbons, polycyclic aromatic hydrocarbons, lead, copper, nickel and cadmium. Seasonal measurements were made, under wet and dry weather conditions, at the same stage of the tide, time of day, and day of the week. Also included in this study was a manhole survey of the Providence sewer system to assess the contributions of these materials from industries. The results should be useful in predicting the effect of runoff on combined sewer overflow discharges and sewage treatment plant output. A report is expected in October 1983.

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7. A STUDY OF THE WATER QUALITY OF THE PAWTUXET RIVER: CHEMICAL MONITORING AND COMPUTER MODELING OF POLLUTANTS

James Quinn and Eva Hoffman GSO
Ray Wright Dept. of Civil Engineering, URI
June 1983-June 1984 $109,000 total funding by R.I. DEM

Objectives

1) To collect data on priority pollutants in the Pawtuxet River and in selected discharges to the river and, coupled with hydrologic data, to develop and calibrate a stream model for predicting pollutant transport in the Pawtuxet River. 2) To provide information for support of future discharge permit decisions.

Project Description

Scientists from the University of Rhode Island, assisted by DEM, will sample north, south and main branch Pawtuxet River surface waters and sediments, and major effluents (industrial and municipal) discharged to the river. Metals, hydrocarbons, priority and non-priority pollutants will be measured in those samples. Intensive 24 hour-sampling will be conducted quarterly, and additional sampling will be conducted during selected wet and dry weather flow periods. Effluents of the major municipal dischargers will be obtained biweekly. The influent to the Cranston plant will also be sampled biweekly to monitor changes in influent quality after the Ciba-Geigy tie-in.

One intensive sampling of the river was completed in June 1983, and the analyses are in progress. The schedule and site selection will remain flexible to permit sampling of areas of particular concern and unusual conditions (storm events). Additional data which would be useful in the calibration of a stream pollutant transport model will be collected. This model should be instrumental in calculating waste load allocations for point source pollution.

SIMULATED ECOSYSTEM EXPERIMENTS

1. FIELD VALIDATION OF FATE AND EFFECTS OF SELECTED TOXIC CHEMICALS DERIVED FROM LABORATORY MICROCOSMS

Ken Perez EPA, Narragansett
Summer 1982-January 1984 $700,000 total funding by EPA

Objective

To measure the dynamics of phthalates in experimental ecosystems and validate with field sampling.

Project Description

Biological and chemical partitioning of phthalates and community structure have been studied in microcosm experiments. In a second phase, the dynamics of phthalates in the field will be studied at sites in the upper Bay (Conimicut Point and Sabin Point) and lower bay (north of Jamestown), as a means of validating the microcosm work. Field sampling for phthalates, initiated in the summer of 1982 and to be concluded in August 1983, is conducted at three month intervals in the following manner: 1) the water column is sampled at surface, mid and bottom depths; 2) sediment cores are obtained by divers at 1 cm intervals to a depth of 7 cm; and 3) body burdens of phthalates are analyzed in the clams, Pitar morrhuana and Nucula annulata with two replicates per station.

2. FATES AND EFFECTS OF NUTRIENTS AND HEAVY METALS ALONG A SIMULATED ESTUARINE NUTRIENT GRADIENT

Michael Pilson MERL, GSO
October 1982-October 1983 $319,405 total funding by NOAA

Objectives

An ongoing eutrophication experiment in MERL mesocosms was begun in June 1981 to address the following questions: a) do nutrient inputs enhance all processes in coastal ecosystems without affecting the function of those systems, or b) do they alter the ability of the systems to transfer material and energy through marine food webs to the point where critical living resources are reduced or anoxia occurs? As a result of the first summer's work, the following research topics were identified for the next year (October 1982 - October 1983): 1) the relationship between copepod abundance and nutrient inputs, 2) the interactions of eutrophication and metal availability, and 3) benthic animal dynamics.

Project Description

The linkage of benthic and pelagic processes and biogeochemical cycling will be examined by measuring benthic nutrient fluxes, benthic respiration, and metal fluxes. The degree to which organic matter and nutrients will be sequestered in sediments will be assessed with mesurements of carbon and nitrogen in bulk sediment samples and profiles of inorganic and organic nutrients. In the summer of 1983 a metal spike will be introduced into the experimental ecosystem, and measurements will then be made of soluble metals, metal cycling and burial and metal concentrations in benthic organisms to evaluate bioaccumulation.

This and other approaches to metal pollution assessment at the Graduate School of Oceanography are outlined in the table which follows. These studies address the fate and effects of metal and the capacity of marine ecosystems to assimilate metals.

Table 1. Summary of General Approach Currently Being Developed or Used at GSO to Assess Fate and Effects of Pollutants or Evaluate the Capacity of Marine Ecosystems to Assimilate Pollutants

General Approaches to Metal Pollution Assessment	Example	References
1) In situ or potential effects based on estimates of metal speciation. Metal speciations are based on combinations of modelling and/or chemical techniques.	1) Zuehlke-Kester thermodynamic model combined with SEPPAK based measurement of Cu-organic complexes. 2) Anodic stripping voltametry estimates of free Cu^{+2}. 3) Metal speciation models combined with bioassay characterization of ligands.	1) Zuehlke and Kester, 1982; Hanson, 1981 2) Piotrowicz et al., 1982; Hutzenga, 1981; Srna et al., 1980; Sugai and Healy, 1978; Batley and Florence et al., 1978. 3) Anderson, pers. com.
2) Estimate in situ metal availability or assimilative capacity by bioassaying with an organism having a lab calibrated response to metal availability. Bioassay procedures involve testing over a range by adding complexing agents or metal.	1) Bioassay using calibrated bacteria. 2) Bioassay using calibrated phytoplankton.	1) Sunda and Ferguson, 1982; Sunda and Gillespie, 1979; Anderson, pers. comm. 1981; Srna, 1980. 2) Sunda and Guillard, 1976; Gavis, 1981; Sunda et al., 1981
3) Estimate potential exposure to added metals by combinations of models of bioavailability and measurements and/or models of processes controlling the biogeochemical fate of added metals.	1) Study dissolved metal-particle interactions. 2) Study process of floculation and sedimentation. 3) Study metal oxidation and reduction reactions. 4) Analysis of the origin, structure and reactivity of potential metal complexing agents.	1) Santschi, 1982 2) Brown and Kester, 1982; Hunt, 1982. 3) Sunda, et al., 1981 4) Harvey and Boran, 1982; Mills and Quinn, 1981; Hanson, 1981; Stuermer and Harvey, 1977.
4) Apply microcosm techniques to estimate fate and effect of in situ or added metals as affected by other pollutants or site specific variables. Estimate effects at ecosystem and any other level of organization of interest. Field validate results with field programs. Directly measure effects on critical living resources.	1) Study effect of eutrophication on bioavailability of in situ metals. 2) Study fate of added metal as affected by eutrophication. 3) Study fate and effect of metal addition. 4) Intercompare utility of alternative approaches (1-4 above) for estimating effect and predicting assimilative capacity.	1) Gamble et al., 1977; Gatcher, 1979.

From table compiled by Percy Donaghay (personal communication)

DECISION TECHNIQUES

1. WATER QUALITY MANAGEMENT IN URBAN ESTUARIES

Stephen Olsen, Donald Robadue, Jr., and Ellen Suchow Forman CRC

July 1982-June 1985 $159,000 total funding by Sea Grant and GSO

Objectives

1. Using Upper Narragansett Bay as a test case, assess the linkages between water quality goals and actual and anticipated pollution abatement activities in an urban estuary.

2. To assemble and apply the results of existing and ongoing scientific research on Upper Narragansett Bay water quality to the planning and capital improvements of the Narragansett Bay Water Quality Management District Commission, the Coastal Resources Management Council and the Department of Environmental Management.

3. To analyze public desires and expectations for water quality improvements compared with the perceptions of those with management responsibilities and scientific interests.

4. In light of the above and based on companion projects, review and recommend changes in water quality planning and research techniques in urban estuaries.

Project Description

The project explores three major aspects of water quality improvement planning: goals and management priorities, ecosystem condition and functioning, and integrated predictive capabilities.

The Clean Water Act of 1972 launched one of the nation's largest construction projects, and a pollution control program with the extraordinarily ambitious goal of fishable and swimmable waters by 1983. At the heart of this initiative was a major federal policy change. The prior approach of enforcement through water quality standards was abandoned and replaced by mandated discharge controls based on the best available pollution control technology. This has led federal and state officials to concentrate on enforcing national effluent standards, hoping that reductions of various pollutants conveyed by "point" sources will bring significant improvements in local receiving waters.

Scientific understanding of marine ecosystems has improved greatly since 1972, yet pollution control programs have exhibited a much diminished interest in actual water body pollution problems and their specific remedies. The problem of determining the likely impacts of pollution control programs on estuarine waters is common to many areas of the nation.

Narragansett Bay offers an excellent test case for developing an approach to water quality management which meshes clearly stated water quality goals with a continuously improving scientific understanding of ecosystem conditions and functioning.

The project team is participating in a process by which Narragansett Bay water quality problems and concerns will be translated into public and private actions needed to achieve goals to improve the condition of the estuary. Use goals will be established followed by the development of requisite water quality goals. These will be translated into pollution abatement options in a form suitable for assessment and prediction. Central to these tasks will be establishing a means by which the newly developed predictive tools and capabilities of the scientific community can be effectively utilized in examining the potential benefits of each strategy upon the estuary. The companion projects (see Crawford, Nixon/Oviatt, Spaulding) will play a key role in supplying the information and concepts necessary to make these judgements.

2. AN ECONOMIC EVALUATION OF ALTERNATIVE WASTEWATER MANAGEMENT STRATEGIES: A CASE STUDY IN THE UPPER NARRAGANSETT BAY

James Opaluch Dept. of Resource Economics, URI

1983-85 $82,000 annual funding by Sea Grant and Agricultural Experiment Station (USDA)

Objectives

1) To evaluate the economic costs and benefits of alternative strategies for controlling pollution inputs into the Upper Bay. 2) To evaluate savings in pollution control costs from policies such as water conservation and separating combined sewer outfalls.

Project Description

This study will interface with ongoing Upper Bay research funded by Sea Grant. The first phase of the project involves collection of data on 1) pollution sources in the Upper Bay, 2) uses of the Upper Bay and its shoreline, 3) location of fish and shellfish grounds and, 4) social and economic variables useful in cost/benefit analysis. In the second phase, a number of policy alternatives will be developed. The third phase will draw on ongoing Sea Grant studies to define pollutant distributions in the Bay and benefits resulting from improvements in ambient pollution concentrations. Finally, the costs of a variety of pollution control strategies wil be analyzed, and cost effective alternatives will be identified.

MONITORING

1. INTENSIVE SURVEY OF THE BLACKSTONE RIVER, PART OF STATEWIDE STREAM SURVEY

Commonwealth of Massachusetts, Dept. of Environmental Quality
Continuous sampling 1-3 days, every 5 days

Project Description

The most recent intensive surveys of the Blackstone River were conducted in June, August, and October of 1980. Twenty-five stations were sampled continuously from Wake Pond to Singleton Street in Woonsocket, R.I. for the following water quality parameters: dissolved oxygen, temperature, and conventional and toxic pollutants. An EPA draft toxicity report, prepared from bioassay studies of the water column, is available. Work is currently in progress to develop a water quality computer model for the upper Blackstone River, to be used in waste load allocations. The next intensive survey of the Blackstone River is planned for 1985.

2. SAMPLES FROM FIELDS POINT SEWAGE TREATMENT PLANT

Narragansett Bay Water Quality Management District Commission

Project Description

Influent and effluent samples from the Fields Point sewage treatment plant in Providence are analyzed daily for pH, total suspended solids, settleable solids, BOD_5, and chlorides; and weekly for cyanide and metals (cadmium, total chromium, hexavalent chromium, copper, lead, mercury, nickel, silver, and zinc). Composite samples for these parameters are collected over a 24-hour period by an automatic sampler at the rate of one sample per hour. Using a flow proportioning procedure in the lab, one composite sample is then obtained for analysis. In addition, grab samples of the effluent are tested for chlorine residual and fecal coliforms.

3. INDUSTRIAL WASTEWATER PRETREATMENT PROGRAM

Charles Krasnoff Associates, Consultants, Providence, R.I.
February 1981-May 1983 $378,000 total funding from EPA

Objectives

1) To establish discharge concentration limits for individual industries

which dump waste water containing pollutants into the Providence sewer system. 2) To identify a mechanism and the legal authority for implementing a pretreatment management program in Providence. 3) To examine the economic impacts of different approaches to industrial pretreatment. The project is based on three concerns: protection of the Fields Point treatment works; protection of the quality of the receiving waters; and protection of the quality of sludge produced by the sewage treatment plant to permit safe disposal.

Project Description

The major parts of this report were the design and distribution of a wastewater production questionnaire to industries and the sampling of a variety of pollutant sources in the Providence area. Heavy metals were sampled from manholes, influents to the Fields Point plant, and industrial discharges. A priority pollutant scan of the influent to the Fields Point plant was also conducted.

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4. E.C. JORDAN CO. PRELIMINARY DATA REPORT
E.C. Jordan Co., Consultants, Portland, Maine
Summer 1982-summer 1983 Funded by EPA

Project Objectives and Description

Manholes (#25 and 36) in Providence and combined sewer overflow (CSO) discharges into the north channel were sampled during three rainstorms for priority pollutants.

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5. RHODE ISLAND DEPARTMENT OF ENVIRONMENTAL MANAGEMENT WATER POLLUTION CONTROL PROGRAM PLAN (106 Program)

General Goals and Program Description

1) Ambient trend monitoring in rivers, shellfish growing areas and bathing areas.

2) Ambient intensive monitoring surveys in rivers and shellfish growing areas.

3) Effluent monitoring of point sources.

4) Calculating the contribution of nonpoint sources to specific water bodies using loading factors from land use maps and field checks for each land use type.

This monitoring program will be expanded, as outlined in Rhode Island's 205 (j) Water Quality Planning Program, to fill in data gaps on priority pollutants above and below major discharges. This data will be used to provide assistance to the state and EPA in a) adopting site-specific water quality standards; b) developing abatement and control requirements including wasteload allocations/total maximum daily loads; and c) assessing program performance.

The details of each monitoring program, pertinent to the Providence River, Upper Narragansett Bay and tributaries are outlined below.

5a. BASIC WATER MONITORING PROGRAM
Division of Water Resources, R.I. DEM and USGS
$27,000 annual funding by State/USGS matching funds

Objectives

To provide estimates of trends in discharge and in water quality parameters in rivers in Rhode Island.

Project Description

The height of the stream is measured with a continuous sampler at 1/2 hour intervals to estimate flow at the following stations:

Blackstone River above Manville Dam
Blackstone River at Millville, MA.
Pawtuxet River at Cranston
Pawtuxet River at Pawtuxet

The following stations are sampled for water quality parameters according to the schedule in Table 2:

Blackstone River at Millville, MA
Blackstone River above Manville Dam
Pawtuxet River at Cranston gauge
Pawtuxet River at Pawtuxet

Water quality parameters are measured from grab samples. With the exception of five-day BOD and bacterial analyses, all the samples are shipped to the USGS laboratory in Atlanta, Georgia for analysis. BOD_5 and decimal dilution total and fecal coliform analyses are performed at the Rhode Island Department of Health Laboratory. The bacterial analyses are also set up by the USGS field people and analyzed using portable membrane filter techniques.

The following stations are sampled for water quality parameters during low flow periods in August and September:

N. Branch Pawtuxet River at Rte. 115 bridge
S. Branch Pawtuxet River at Centerville bridge

Biological monitoring employing the use of artificial substrates will be conducted by the water quality section at the stations sampled by the USGS.

TABLE 2. Sampling Strategy for Water Quality Parameters, Basic Water Monitoring Program

Sampling Frequency	Parameter
Monthly	Stream flow Temperature Dissolved Oxygen pH Conductivity Nutrients
Bimonthly (Jan, Mar, May, July, Sept, Nov)	BOD_5 Coliforms (Total & Fecal)
Quarterly (Mar, Jun, Sept, Dec)	COD ROE, 105°C, Suspended Residue on Evaporation ROE, 105°C, Total Residue on Evaporation Turbidity
Semi-annually (Mar, Sept)	Inorganics (Ca, Mg, K, Na, Cl, SO_4) Color, alkalinity, pH, phenols, oil and grease
Annually	Metals in water column Pesticides in water column Pesticides in bottom material

5b. SHELLFISH GROWING AREA MONITORING
R.I. DEM and Division of Food
Protection and Sanitation, R.I. Department of Health
1967-ongoing State Funding

Objectives

To identify pollutant trends and potential human health hazards in shellfish tissues and water in Narragansett Bay.

Project Description

Water samples are collected on a year-round basis (weather permitting) for total and fecal coliform bacteria.

In addition, quahogs and the tissues are sampled twice a month (beginning of 1st and 3rd weeks) by DEM boat, and the tissues are analyzed by the Department of Health for total and fecal coliforms and heavy metals (Cd, Cu, Cr, Pb, Zn).

The stations sampled in Upper Narragansett Bay are as follows:

Providence River, north of Bullocks Point
Providence River, west side
Providence River, east side
Longmeadow region in Warwick, south of Conimicut Point
Mouth of the Warren River
Ohio Ledge
Mount View in North Kingstown
Mount Tom Rock, NE of Prudence Island
Breakwater at Wickford
Potter's Cove, east side of Prudence Island

5c. BATHING AREA MONITORING
Division of Water Resources, RI DEM
Summers only Funding by State/EPA

Objective

To monitor the water quality near Rhode Island beaches

Project Description

During the summer of 1983 water samples will be analyzed for total/fecal coliforms on a weekly basis. Grab samples will be collected near the following beaches in Upper Narragansett Bay:

Barrington Town Beach
Conimicut Point Beach
Warren Town Beach

5d. INTENSIVE RIVER SURVEYS

Division of Water Resources, R.I. DEM

Funding by State/EPA

Objective

To show a cause and effect relationship between wastewater discharges and water quality.

Project Description

Samples of rivers and waste sources are collected for a 24 hour period during low river flow conditions. This provides an estimate of the diurnal variation of a number of water quality parameters. The parameters measured vary, depending on the point source (see Table 3). The Branch River and the Blackstone River were sampled during the summer of 1983.

5e. EFFLUENT MONITORING OF MUNICIPAL WASTES

Division of Water Resources, R.I. DEM

Project Description

The following municipal wastewater treatment facilities discharging to tributaries to the Upper Bay are sampled:

Blackstone Valley District Commission
Bristol
Burrillville
Cranston
East Greenwich
East Providence
Providence
Warwick
West Warwick
Woonsocket

These facilities are sampled on a monthly basis for the parameters outlined in Table 4.

Plants with industrial process waste in their influent sewage will be sampled, raw and final effluent, once per year for organic chemicals. This is in addition to planned river studies and work being done by communities on their pre-treatment programs.

Plants tributary to shellfish growing areas (see list above) are spot checked weekly for chlorination treatment. Final effluent grab bacteriological samples are also collected at that time.

TABLE 3. Water Quality Parameters Measured In Intensive River Surveys

Parameter	Sample Type	Frequency	Total # of Analyses per Station
Dissolved Oxygen	Meter	3 hours	8
Total & Fecal Coliforms	Grab	6 hours	2
Turbidity, Total Alkalinity, pH, BOD_5, Suspended Solids, Color, NO_2-N, NO_3-N, MBAS, Hardness	Composite	3 hr. for 6 hr.	4 (each from 2 composited samples)
NH_3-N, Total Phosphorus	Composite	6 hr. for 24 hr.	1 (from 4 composited samples)
Metals (Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn)	Composite	6 hr. for 24 hrs.	1 (from 4 composited samples)
Volatile Organics	Grab	1 sample	1

TABLE 4. Water Quality Parameters Measured at Wastewater Treatment Facilities

Parameter	Sample Type	Raw Sewage	Final Effluent
pH	composite	X	X
Suspended solids[1]	composite	X	X
Settleable solids	composite	X	X
BOD_5	composite	X	X
Total Coliform	grab		X
Fecal Coliform[2]	grab		X

[1]Tested weekly in final effluent of Providence plant if conditional area in the Bay open.

[2]Tested weekly in final effluent of all municipal plants if conditional shellfish area in Bay open.