EPSCoR Pre-Proposal: Biological Consequences of Environmental Change: Building a Regional Foundation for Ecosystem/Environment Research at the Marine/Terrestrial Interface.

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Proposal Objective

We propose to build a strong scientific and technological program for studying biological consequences of environmental change. The core of the program will be the creation of an integrated system for continuous 4-D characterization of biological and environmental change in the Narragansett Bay watershed. Components of the program will include:

I. Creation of an integrated system for continual *in situ* analyses and data reporting at multiple sites.
II. Development and testing of new biological and biogeochemical sensors.
III. Integration into the data system of external records of biological and environmental change.
IV. Development and testing of a predictive, coupled physical-biological model of Narragansett Bay.

The program will be fully multi-institutional. Program management, direction, education and outreach will be overseen and undertaken by scientists from multiple Rhode Island institutions of higher education. All institutions of higher education, state agencies, environmental organizations and the general public will have direct access to the data.

Science Objective

The overarching scientific objective of this program is a synoptic view of how biological processes and properties in the Narragansett Bay watershed (such as productivity, respiration and biogeochemical transformations) respond to local environmental changes [e.g., wastewater (nutrient) discharge and other industrial activities] and regional and global environmental changes (e.g., climate change).

Outcomes

- The project will provide continuous 4-D characterization of biological and environmental change throughout the Narragansett Bay watershed.
- The project will form the scientific basis on which researchers in Rhode Island (and beyond) can build experimental and theoretical studies of biological responses to environmental changes (e.g., global climate change and local anthropogenic changes).
- It will be the national model for demonstrating how continuous bio-physical measurements of a complex region can be used to (a) better understand and improve predictions of biological responses to environmental change, and (b) to provide the critical information to scientists and decision-makers require to study and manage complex coastal ecosystems.
- Stations will serve as test sites for new biological, chemical and physical sensor development, testing, and package integration (such as development of an *in situ* coliform sensor).
- The data management system will link environmental data to basic biological data. It will provide a model for how to deal with diverse (*in situ*) datasets from a very heterogeneous environment.
- The project will provide a coupled biological-physical model that can be used to assess current and future responses to changes in climate, land-use patterns, nutrient reductions and other environmental factors.

Project Advantages

- This program will position RI institutions to play a prominent role in major national science initiatives, such as the NSF Ocean Observing Initiative, the NSF Cyberinfrastructure Initiative, the NSF Biocomplexity Program, and the NSF Long Term Ecological Research Program.
- The program will provide a strong base for direct cooperation between RI academic institutions, state agencies (such as the RI Department of Environmental Management, Narragansett Bay Commission, Coastal Resources Management Council, and the Governor's Bay Commission), federal agencies (such as NOAA National Marine Fisheries Service, NOAA National Estuarine Research Reserve System, US DoD Naval Undersea Warfare Center, and EPA National Estuary Program), and non-governmental organizations (such as Save the Bay) to solve immediate and future environmental challenges in Rhode Island.
- The program will provide a strong foundation for scientific training and research by involving researchers and educators from a number of higher-education institutions (initially URI, Brown University and Roger Williams University).
- The program will support direct interaction between the proposing universities and local marine and environment-focused industry (e.g., Raytheon, NUWC subcontractors, SAIC, ASA, SubChem Systems, WetLabs, YSI).
- The program will provide a mechanism for increasing K-12 educational opportunities through linkages with Rhode Island's NSF-sponsored GEMS-NET program.
- The program will provide near-real time access to environmental data and predictive tools that will enable the State to assess current and future impacts on the biology and water quality of Narragansett Bay.

Background

Rhode Island and its waters lie at the interface of multiple land and ocean climatic provinces. The combinations of ocean and land geography, temperature, precipitation, elevation, and soil type found in the Rhode Island Basin make for one of the most diverse biological ecosystems in North America. Many marine and terrestrial species in Rhode Island are at the limit of their climatic range with typical "cold" species overlapping with "warm" species. As such, the region's biology is critically sensitive to seasonal, annual, decadal and longer-term climate variations. The Rhode Island waters and landscape are undergoing significant alteration as local land and water uses change. Rhode Island is sensitive to global climate change and its driving factors like long-lived carbon dioxide. Rhode Island is also at the receiving end of much of the North American short-lived gaseous and particulate pollution, as well as the local introduction of aquatic pollutants by rivers and boats/ships.

The biology and water quality of Narragansett Bay is central to the quality of life, economics, and growth potential of Rhode Island. However, the RI scientific community and the State do not have a set of integrated analytical tools to assess the impact on marine ecosystems of changes in the environment due to natural or human activities. The goal of this project would be to develop some well-grounded tools that can be used to assess the response of the Bay (and other regional waters) to a variety of environmental changes. For example, how will the biologic composition and diversity, water quality, and the severity and extent of hypoxia in Narragansett Bay be affected by changes in climate, land use, and wastewater treatment facilities? How is the distribution of populations (genomes) controlled by the circulation and chemistry of the Bay? The answers to these types of question are vital to the management of the Bay, to the quality of life and economics of Rhode Island, and to the general scientific understanding of estuarine ecosystems.

The answers to these questions cannot be resolved without reliable observational systems and predictive tools that integrate the climate, circulation, and biogeochemistry of the bay. RI DEM currently plans to develop a rigorous monitoring system for freshwater tributaries to the bay. However, the Rhode Island scientific community does not yet have an integrated system to address these questions for the bay or the watershed as a whole. We propose to create that system.

Project and Management Plans

To ensure the multi-institutional nature of the project, a Project Oversight Committee (POC)will be established to manage the program. It will be composed of co-investigators or other relevant representatives of proposing institutions. The POC will be advised by four panels: a Data Structure Advisory Panel (DSAP), a Sensor Advisory Panel (SeAP), a Station Advisory Panel (StAP), and a Modeling Advisory Panel (MAP). Each panel will have a clearly focused mandate. The DSAP will be charged with defining how the program's data must be organized and made accessible to ensure its maximum utility for the broader community, including researchers, policy makers, and educators. The SeAP will be charged with identifying the sensors that should be part of the standard array at each monitoring site, and with advising the POC on issues related to sensor development. The StAP will recommend exact locations for monitoring stations and the order in which the individual stations should be created over the three years of EPSCoR funding.

Each panel will be composed of approximately five members, to be principally drawn from relevant representatives of the proposing institutions. To guarantee the program's broader relevance, the panels will also include representatives from relevant state agencies, local organizations, and relevant industry partners. The proponents are open to suggestions for individual panel members. The staff will directly report to the POC or its designated representative.

If the program that we propose is funded, we will notify the broader Rhode Island community of its existence and accessibility by (1) posting in local media an invitation to potential users, (2) mailing notices to key individuals at relevant state agencies and local organizations, and (3) instituting a program website, which will provide direct access to data along with a description of the program, its site locations, its management structure, and contact information.

The data distribution system will be developed to provide rapid, web-based access to the data and information the program creates. It will serve the scientific and resource management community as well as the public. The data access portal will occur within existing data dissemination systems administered through CELS (e.g., www.narrbay.org, www.edc.uri.edu/rigis) and GSO (e.g., www.unidata.ucar.edu/packages/dods/). Furthermore, the data portal system will be fully compliant with federal geospatial data and metadata standards and serve as a local node on the National Spatial Data Inventory Clearinghouse.

Project Requirements

Data System Requirements.—To maximize the utility of the proposed program, its data system will be carefully structured. It will provide uniform and rapid access to environmental and biological data holdings from small programs with individual data stores. The organizational structure of data at the various storage sites, data acquisition procedures, and quality control procedures will need to be consistent. The system will provide long-term access to records. To ensure easy access to a broad range of users, the data will be organized and maintained in formats that are platform-independent (accessible via all common computer systems). External data sets, such as RI DEM freshwater monitoring records, local and regional climate records, NOAA PORT records and "legacy data sets" (ongoing long-term biological and environmental records) must be appropriately integrated. The data must be organized in a manner that will render it appropriate for continuing the data series well into the future. The Coastmap System developed by Malcolm Spaulding and currently used by the NBC, and the OpenDAP system developed by Peter Cornillon and promoted by NSF, have many of the characteristics necessary for real-time reporting and synthesis of data.

Station Requirements.—Sensor stations must be placed throughout the bay in critical locations to meet the needs of scientists, policy makers, bay users and others (e.g., Fig 1). To create comparable data throughout the region, each sensor station will include a basic instrument package that is standardized to the maximum extent possible (with identical sensors making similar measurements at similar sampling frequencies, etc). Some stations will be mounted on a bottom mooring with a winch (so the entire water column can be characterized and so stations in the upper bay will be operational during winter ice conditions). Each station will be telemetered (to submit data to shore in real time) and will have the capability for adding additional sensors, such as experimental biosensors, as appropriate.

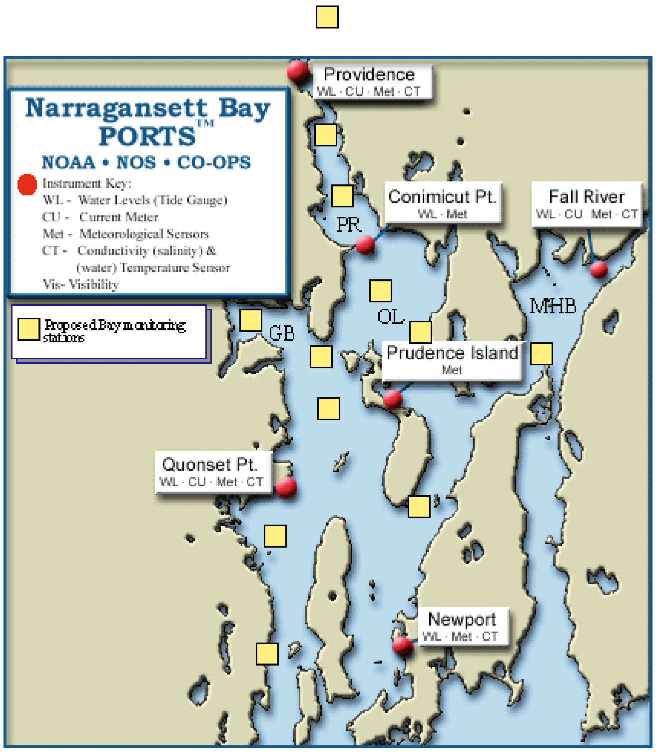

Figure 1: Map of Narragansett Bay showing the locations of proposed monitoring stations (squares). Locations of existing PORTS stations are also indicated (circles). Sampling coverage is focussed within the upper portion of the Bay, where previous and ongoing studies indicate key biochemical processes are occuring. Recent physical observations made within this region have also identified key sub-regions with restricted flushing and high residence time. Key sub-regions to be monitored include the Providence River (PR), Greenwich Bay (GB) and Mt. Hope Bay (MHB), along with the apparent mixing zone of Ohio Ledge (OL). Additional stations in the lower Bay are included to document far field effects and to provide key information for model calibration.

Sensor requirements.—The instrument package for each bay station will contain a variety of sensors to continuously document biologically controlled conditions (such as concentrations of chlorophyll, dissolved oxygen, and dissolved nutrients) and environmental variables (salinity, temperature, turbidity, tidal variation, current strength and direction). To ultimately document a broader range of biological responses, novel *in situ* biosensors will be required. Consequently, we propose to support development of experimental biosensors and testing of those sensors at individual bay stations. The experimental sensor program will initially focus on rendering experimental biosensors routinely operable [such as (I) the in situ sensor to quantify sewage-derived bacteria, currently under development by Al Hanson and David Smith, (II) other biomolecular sensors, and (III) sensors needed for the coupled bio-physical model (e.g., optical sensors for zooplankton biomass)].

Model Requirements.—Our goal is to develop a predictive tool to simulate biologic processes in Narragansett Bay. This tool will be used to predict how biological processes might change given changes in natural and human-induced forcing. We will use an existing hydrodynamic model (ROMS) and the proposed data from the sampling array as the basis for this predictive tool. ROMS is currently running on a workstation cluster at URI GSO. It simulates currents, and the transport of salt and heat on a 3-dimensional grid extending from the Providence River to RI Sound. ROMS 2.0 (the latest version) has the capabilities to incorporate nutrients, carbon, oxygen, phytoplankton and zooplankton. All of these biologic components are complex and need to be tailored to the Narragansett Bay system. This component requires expertise in the physical hydrodynamic model to adapt it to the appropriate scales and in the biologic systems and how they are captured in the coupled model.

Pre-proposal Description Requirements

1) Current status of the research area.—This project makes sense for Rhode Island and the proposing institutions because:

- Rhode Island researchers have strong experience in data integration and development of environmental data systems [e.g., Peter August (URI CELS), Peter Cornillon (URI GSO), Malcolm Spaulding (URI OE)].

- Rhode Island researchers [e.g., Al Hanson, David Smith, James Miller (URI)] and local companies (e.g., SubChem Systems, WetLabs, and YSI) are experienced in environmental sensor and biosensor development.
- Rhode Island scientists have strong experience in local biological and environmental monitoring (e.g., John King, Chris Kincaid, Candace Oviatt, Paul Hargraves, Jeremy Collie, Ted Smayda, Jon Boothroyd, Malcolm Spaulding and Art Gold at URI and Warren Prell, David Murray, Jon Witman, Mark Bertness at Brown University). Several biological and environmental time series have been sustained for several decades at individual stations (such as the URI GSO plankton, fish, beach, and water-column surveys). These time series were recently expanded to include molecular characterization of the annual succession of bacterioplankton (David Smith, URI) and cyanophage diversity (viruses that infect cyanobacteria) (Marcie Marston, RWU).
- Narragansett Bay areas of greatest potential biological and environmental change can be readily identified on the basis of abundant biological and environmental data (from both academic and non-academic organizations).
- Initial application [by Chris Kincaid (URI)] of the ROMS hydrodynamic model indicates that it is appropriate for Narragansett Bay and will b e a useful predictive tool.
- There is very strong state interest in monitoring and improving the health of Narragansett Bay.

2) New activities to be funded by RI EPSCoR.— (I) Creation of an integrated watershed bay-wide system for characterizing biological and environmental change. (II) Creation of a data management system that will link environmental data to basic biological data and make the data available to scientists, policy makers, educators, and others. (III) Development and testing of novel *in situ* biological, chemical and physical sensors. (IV) Development of a coupled physical-biological predictive system for assessing biological impacts in Narragansett Bay of environmental change.

3) Specific barriers to national research success to overcome.—(I) To initiate an integrated program of this magnitude is beyond the funding and organizational reach of traditional single-investigator programs. (II) Lack of an integrated climate-ocean-biology model for Narragansett Bay limits the ability of Rhode Island scientists to address local and regional responses to environmental change. (III) *In situ* long-term biosensors are a crucial component of the NSF Ocean Observing Initiative, but are very limited in type and only exist as experimental models.

4) Plans to engage faculty and students from other Rhode Island institutions.—The program will be fully multi-institutional. It will be managed and used by faculty and students from URI, Brown University, and Roger Williams University.

5) Potential for technology commercialization.—The potential for technology commercialization is strong, particularly with respect to biosensor development and environment monitoring systems.

6) Opportunities to enhance the flow of students into STEM areas of higher education (particularly women and underrepresented minorities).—(I) Faculty and students at URI, Brown, and Roger Williams University will incorporate the results of the measurements and modeling into classes, student theses and undergraduate projects. (II) New classes on oceanographic instrumentation will be developed and taught at URI. (III) Graduate students and upper-class undergraduates will be directly involved in the biosensor development and model development efforts of this program.

7) Projected competitive stature of the research team.—Very high, once the EPSCoR investments have occurred. The RI scientific community will be able to pose new questions and write new proposals to NSF and other funding agencies on the basis of the new data sets, sensors and predictive tools developed in this project.

8) Demonstration of institutional commitment.— Throughout Rhode Island, academic institutions, governmental agencies, and non-governmental organizations are strongly committed to monitoring and modeling of biological processes in the Narragansett Bay watershed. For one example, the Governor's Narragansett Bay Commission will strongly recommend that the State fund significant improvements in environmental monitoring of Narragansett Bay. For a second example, the Narragansett Bay Commission and the Narragansett Bay National Estuarine Research Reserve staff have indicated willingness to provide some technical and operational assistance. Statewide academic and non-academic commitment will be thoroughly outlined in a full proposal.

Draft Budget

To develop and maintain the proposed data structure and bay monitoring program, we request funding for two staff FTEs and three graduate students per year (Table 1). One FTE will be tasked with creating the data structure recommended by the POC and the DSAP. This FTE will be ultimately responsible for integration, synthesis, and presentation of the data generated and incorporated by the project. One graduate student will be charged with data "harvesting," identification, collection and input of data from the project sites and from external sources of relevant data (such as NOAA port records, local climate records, and other relevant biological and environmental records). One FTE and two graduate students will be required for installation and maintenance of the proposed sensor stations.

We request $100K/year for development and testing of a Narragansett Bay coupled biological-physical model. We also request $150K/year to support development and testing of novel sensors, such as the *in situ* bacterial sensor being developed by Al Hanson and David Smith (URI), other biomolecular sensors, and optical zooplankton sensors. These funds may support up to five additional graduate students per year.

Finally, we request funding for hardware to instrument twelve stations for biological and environmental bay monitoring ($75K per station), and for hardware to integrate biological monitoring capabilities into six existing NOAA PORT monitoring stations ($40K each) (Table 2).

Table 1: Approximate budget.

BUDGET ITEM	**YEAR 1**	**YEAR 2**	**YEAR 3**	**TOTAL**
HUMAN RESOURCES				
Two staff FTEs	200K	200K	200K	600K
Three graduate students	150K	150K	150K	450K
PHYSICAL RESOURCES				
Equipment/sensors for new bay stations (4/yr)	300K	300K	300K	900K
Sensor enhancement of PORT stations (2/yr)	80K	80K	80K	240K
DEVELOPMENTAL RESOURCES				
Model development	100K	100K	100K	300K
Sensor development	150K	150K	150K	450K
Total	$980K	$980K	980K	$2940K

Table 2: Approximate cost per station.

Sensor	**New Stations**	**NOAA PORTS Stations**
Salinity	$ 1,000	
O_2	$ 4,500	$ 4,500
Nutrients	$ 30,000	$ 30,000
Tide gauge	$ 3,000	
Current meter	$ 13,000	
Winch	$ 14,500	
Chlorophyll	$ 3,000	$ 3,000
Temperature	$ 500	
Turbidity	$ 1,500	$ 1,500
Telemetry	$ 4,000	$ 2,000
Total per Station	$ 75,000	$ 40,000