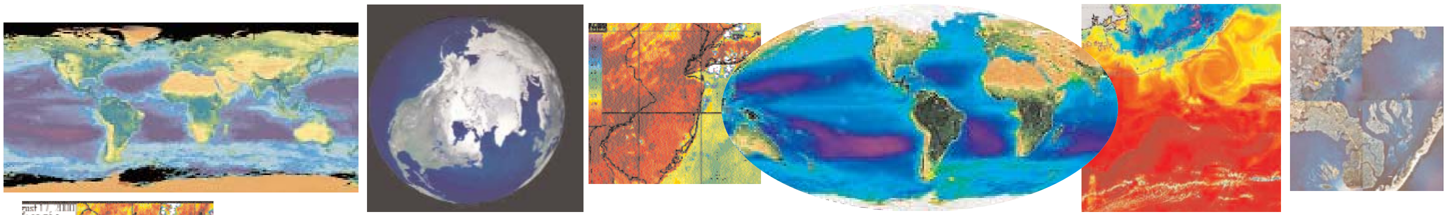

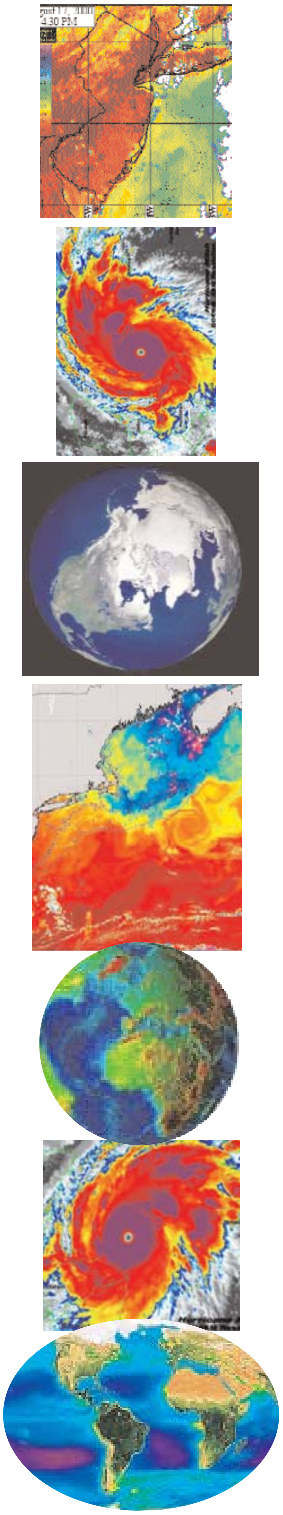

Proceedings from the
NOAA-Supported Workshop

Linking Elements of the Integrated Ocean Observing System (IOOS) with the Planned National Water Quality Monitoring Network

19-21 September 2005

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Sea Grant New Jersey
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · NOAA · U.S. DEPARTMENT OF COMMERCE
NEW JERSEY MARINE SCIENCES CONSORTIUM

PROCEEDINGS FROM THE NOAA-SUPPORTED WORKSHOP

LINKING ELEMENTS OF THE

INTEGRATED OCEAN OBSERVING SYSTEM (IOOS)

WITH THE

PLANNED NATIONAL WATER QUALITY MONITORING NETWORK

(NWQMN)

WORKSHOP CO-SPONSORS

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NEW JERSEY SEA GRANT

UNITED STATES GEOLOGICAL SURVEY

RUTGERS UNIVERSITY

AND THE

MID-ATLANTIC OCEAN OBSERVING SYSTEM
REGIONAL ASSOCIATION (MACOORA)

EXECUTIVE SUMMARY

The National Oceanic and Atmospheric Administration (NOAA), in cooperation with the New Jersey Marine Sciences Consortium (NJMSC), hosted a workshop at Rutgers University on 19-21 September 2006 to explore ways to link the Integrated Ocean Observing System (IOOS) to the emerging infrastructure of the National Water Quality Monitoring Network (NWQMN). Participating partners included the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA), U.S. Geological Survey, Rutgers University Coastal Ocean Observing Laboratory (COOL), and the New Jersey Sea Grant College. The workshop was designed to highlight the importance of ecological and human health linkages in the movement of materials, nutrients, organisms and contaminants along the Delaware Bay watershed-estuary-coastal waters gradient (hereinafter, the "Delaware Bay Ecosystem [DBE]"), and to address specific water quality issues in the mid-Atlantic region, especially the area comprising the Delaware River drainage and near-shore waters. Attendees included federal, state and municipal officials, coastal managers, members of academic and research institutions, and industry representatives.

The primary goal of the effort was to identify key management issues and related scientific questions that could be addressed by a comprehensive IOOS-NWQMN infrastructure (US Commission on Ocean Policy 2004; U.S. Ocean Action Plan 2004). At a minimum, cooperative efforts among the three federal agencies (NOAA, USGS and EPA) involved in water quality monitoring were required, but the U.S. Ocean Commission Report also recommended outreach to states, regional organizations and tribes to determine their specific needs, and to develop an efficient system of data gathering, QA/QC protocols, product development, and information dissemination.

Plenary Presentations

Invited speakers were asked to summarize current national and regional environmental monitoring programs, observational capabilities and ecological studies in general and plenary sessions:

Water Quality Issues (Jawed Hameedi, NOAA). A nation-wide perspective on water quality-related resource management issues in the coastal zone such as habitat loss or adverse modification, coastal erosion and shoreline armoring, frequency of harmful algal blooms, shellfish bed closures and fish consumption advisories due to pathogens and toxic chemicals, oxygen depletion events, and loss of biodiversity. Also emphasized was the need for developing relevant research and monitoring strategies that also involve aspects of social and economic sciences, application of new technologies and the risk assessment paradigm.

National Coastal Assessment (Barry Burgan, U.S. Environmental Protection Agency). A national survey of water and sediment quality, coastal habitat loss, benthic community condition, and fish tissue contaminant levels that concluded coastal water quality conditions in the nation were at best fair (National Coastal Condition Report, II 2005).

Water Quality Monitoring: Delaware Bay Watershed (Eric Vowinkel, U.S. Geological Survey). Although numerous water quality-monitoring surveys are now underway above the head of tide, improved agency coordination and more efficient data dissemination will be necessary to accurately determine region-wide sources, loads, and levels of contaminants.

Water Quality Monitoring: New Jersey Coastal Waters (Robert Connell, New Jersey Department of Environmental Protection). Coastal monitoring directed at human health through compliance with the National Shellfish Sanitation Program. The effort includes a growing network of real-time water quality sensors that complement traditional monitoring methods.

Sediment Dynamics: Delaware Bay Ecosystem (Chris Sommerfield, College of Marine Studies, University of Delaware). To facilitate trend analyses and predictive modeling, managers, engineers and scientists will require system-wide time series measurements of water column and sediment parameters to better address sediment related management issues.

Coastal Oceanography: New Technologies (Scott Glenn, Oscar Schofield and Robert Chant, Institute of Marine and Coastal Sciences, Rutgers University). Components of the COOL and associated ecological programs on the continental shelf can be applied to the Delaware Bay Ecosystem but will require applications and upgrades of existing remote sensing capabilities and the cabled network to facilitate integration into the broader national landscape of ocean observing systems.

Long Term Trends: Delaware River and Estuary (Jonathan Sharp, College of Marine Studies, University of Delaware). While long-term trends in dissolved oxygen concentrations in the river and estuary have shown improvement, there are ongoing concerns that increased phytoplankton production may result in the re-occurrence of hypoxia in the tidal fresh portion of the river.

Delaware Bay Ecosystem (Michael P. Weinstein, New Jersey Marine Science Consortium). Independent research conducted by NJMSC, the University of Delaware, the Sea Grant College Programs of Delaware and New Jersey (including related extension services), and other funded studies on Delaware Bay have led to improved understanding of ecosystem responses to anthropogenic and natural influences. Closing substantial gaps in our current understanding of secondary production and recruitment success of finfish and shellfish, ecosystem dynamics, biogeochemical cycling, disease epidemiology, chronic impacts of pollutants, effects of habitat loss and degradation on essential fish habitat will all, however, depend on our ability to integrate future ecological studies with an emerging IOOS-NWQMN infrastructure.

Data Management and Information Products (Antonio Baptista, Oregon Graduate Institute, School of Science and Engineering, Oregon Health and Science University). Pilot ocean observing systems (Northwest Association of Networked Ocean Observing Systems [NANOOS]) and a pilot environmental observation and forecasting systems (EOFS) already exist, their technology transfer and "lessons learned" raises the possibility for a successful NWQMN-IOOS linkage for the Delaware Bay Ecosystem.

Breakout Sessions

Plenary presentations were followed by focused breakouts and report back summaries designed to capture the needs of potential users. Four challenge questions framed the breakout discussions:

- What water-habitat quality *issues and needs* will be addressed by a NWQMN/IOOS Linkage?
- What are the *current data gaps*?
- How do we assure *data integration* across regions?
- What should the *federal backbone* of a combined IOOS - NWQMN look like?

Workshop participants were also asked to recommend core measurements (based on common protocols for data management and dissemination) that would comprise the "national backbone" and be useful to the broadest possible spectrum of users. The development of a regional pilot for water quality monitoring (physical, biological and chemical parameters) was considered essential for linking IOOS and NWQMN to Integrated Coastal Zone Management (ICZM) decisions affecting sustainable uses of coastal resources and preserving the health of coastal ecosystems.

Workshop Results (Outcomes)

The three-day effort resulted in several end-products, including (1) an analysis of existing monitoring programs – assessing their strengths and weaknesses and identifying gaps in existing architecture, (2) evaluating the effectiveness of existing data management infrastructure, and (3) determining the availability of current procedures and technologies for addressing specific regional water quality and ecological issues. Pilot projects were considered essential for demonstrating the cost-effectiveness of an integrated IOOS-NWQMN framework for addressing regional water quality characterizations. Ultimately, such information would be incorporated into national Ecosystem Approach to Management (EAM) initiatives and the creation of regional ocean governance frameworks.

Outcome #1

Any future management scenario will require a centralized effort to integrate the largely independent monitoring and research programs now being conducted by participating federal, academic and state agencies. An *integrated* monitoring system, at the proper spatial and temporal scale, including real-time (continuous) data collection, will go a long way towards minimizing data gaps and improving information products designed to forecast and respond to natural and anthropogenic stressors. Comparable and compatible data should be available on a regional server housed at a single location, and supported by federal funding. The data management system should be user driven and capable of data delivery and on-line production of data summaries and reports.

Extant Federal programs that can serve as core observing systems for an integrated monitoring network for the Delaware River and Estuary include the National Coastal Assessment (NCA), National Water Quality Assessment (NAWQA), National Stream Quality Accounting Network

(NASQAN), Monitoring and Event Response from Harmful Algal Blooms (MERHAB), National Status and Trends Program (NSTP) and Physical Oceanographic Real-Time System (PORTS). These programs complement existing regional monitoring activities, for example, the Delaware Estuary Observing System (DEOS) at the University of Delaware and water quality monitoring by the Delaware River Basin Commission (DRBC).

Outcome #2

The DBE was judged to be a suitable location for developing a national pilot for the National Water Quality Monitoring Network. The landscape advantages and management challenges offered by this system range from its geometric regularity and dominance by a single un-dammed river, to its world renowned populations of horseshoe crabs, shorebirds, anadromous fish and shellfish, to the need for protecting potable water that serves approximately 16 million people, and finally the system's "natural laboratory" setting of heavily urbanized and industrialized shorelines to the north and nearly pristine habitats to the south. To conserve the region's coastal resources and amenities, and improve the region's economic vitality -- a large part of which is derived from the coastal zone -- will require the infrastructure of a combined IOOS-NWQMN and the application of a broad suite of environmental indicators – both ecological and socio-economic – to support science-based policy and informed decision making.

Outcome #3

Numerous overarching water quality management issues for the DBE were identified during the workshop:

- Dredging (e.g., altered hydraulic geometry, widespread bottom and marshland erosion, salt intrusion, sediment removal from non-dredged areas)

- Freshwater Quantity and Quality (e.g., alteration or reduction of freshwater flow due to increased usage, rising sea level or channel deepening)

- Public Health (e.g., beach contamination, seafood consumption advisories)

- Habitat Loss or Population Decline in Key Species (e.g., Eastern oyster, horseshoe crab, American shad)

- Nitrogen Loading and Nutrient Imbalance (e.g., biogeochemical cycles, potential for harmful algal blooms [HAB])

- Climate Change and Extreme Natural Events

Recommendations

The following recommendations were recorded at the workshop:

1. The Delaware Bay Ecosystem region would be ideally suited for attempts to link the IOOS with planned components of NWQMN through (a) integration of existing discrete sampling sites and monitoring networks, (b) addition of supplemental monitoring from ferries and/or autonomous underwater vehicles, (c) incorporation of existing air deposition sites and networks, and (d) enhancement of existing arrays of shore-based, aircraft or space-borne sensors. Current assets should be utilized to develop a cost-effective and comprehensive monitoring program that links system components of the DBE to serve regional needs, and contribute to broad societal goals that have been identified for the U.S. Integrated Ocean Observing System.
2. Because contaminant inputs to the DBE can be hemispheric, regional or local, broad geographical coverage, comparable data and an integrative approach to water quality monitoring are essential; any future IOOS-NWQMN should be tailored to meet specific resource management goals.
3. Probabilistic and systematic ("targeted") sampling approaches are both necessary for water quality monitoring and data generation, and should be developed on a complementary basis.
4. The temporal and spatial scale of monitoring should be enhanced by application of new sensors and observation technologies (e.g., autonomous underwater vehicles, fluorometry, acoustics, and biomarkers).
5. The determination of *what to monitor* should be strongly linked to current or future management and ecological issues (an example of the latter might include the loss of wetlands due to sea level rise), and be consistent with requirements for natural resource models in the region (e.g., models describing oyster recruitment and incidence of disease); monitoring data should be appropriate for forecasting conditions in unmonitored areas or time frames.
6. A data clearinghouse should be developed that links real-time and archived data while assuring timely delivery of quality assured data in easily accessible formats, preferably through a web-based portal.
7. The Delaware Bay Ecosystem should be used as a pilot or proof of concept model for a linked IOOS-NWQMN, in particular by utilizing IOOS observational assets and data management protocols.

PREFACE

The United States has made considerable progress during the past two decades to improve water quality in both fresh and coastal waters through effective point source ("end of pipe") and source control technologies. In addition, the production and/or use of several toxic and environmentally persistent chemicals, among them polychlorinated biphenyls (PCBs) and chlorinated pesticides, has been eliminated or severely curtailed. Yet, despite this progress, many coastal water bodies and streams still fail to attain water quality standards and designated use criteria, due largely to non-point source pollution, legacy contaminants (e.g., PCBs, mercury) and contaminants that are transported globally and deposited far from their origins.

There is considerable evidence that water quality degradation continues to impair the use of coastal and estuarine resources, leading to:

- Excessive algal growth and loss of aquatic vegetation;
- Occurrence of harmful algal blooms (HAB);
- Protracted, recurring or episodic hypoxic (or anoxic) conditions;
- Accumulation of toxic chemicals in food webs leading to seafood consumption advisories;
- Beach and shellfish bed closures; and
- Declining wildlife populations, fish and shellfish stocks and biodiversity.

The Delaware River and Estuary

The Delaware River Estuary system is characterized by one the largest un-dammed stretches of a large river in the United States, a watershed that includes all major forest types of the Eastern United States, and a large estuary that is home to the largest population of horseshoe crabs in the world and an important habitat in the migratory corridor of shorebirds and waterfowl. Finfish and shellfish fisheries remain important commercial resources in Delaware Bay. A nearly continuous stretch of relatively undisturbed tidal wetlands ring most of the Bay shoreline south of the Delaware Memorial Bridge (river kilometer 130)

However, three major cities and heavy industry are concentrated in the upper brackish-tidal fresh portion of the estuary, and one of the nation's largest freshwater ports (Philadelphia-Camden) is also located here. The human population in the surrounding watersheds exceeds 9 million. As a result, water quality related issues in the Delaware region focus on: the preservation and delivery of potable water, hydrodynamic impacts due to dredging and altered bathymetry; widespread substrate and marsh erosion, fish consumption advisories, population recovery of key species (e.g., Eastern oyster, horseshoe crab, American shad), and nitrogen overload and nutrient imbalance in the estuary.

In its hallmark report entitled "An Ocean Blueprint for the 21st Century," the U.S. Commission on Ocean Policy offered more than 200 recommendations that focused on improved ocean management and governance, sustainable uses and stewardship of ocean and coastal resources, understanding of ocean-land-atmosphere connections, implementing ecosystem-based management, and achieving a sustained Integrated Ocean Observing System (IOOS) through technology development and delivery of information and products to a broad user community. The Commission also recommended the development of a comprehensive and integrated National Monitoring Network to focus on important resource management issues, including water quality.

The design for a National Water Quality Monitoring Network has been recently advanced based largely on the recommendation appearing in the U.S. Commission on Ocean Policy report, and subsequently included in the U.S. Ocean Action Plan. The proposed Network would be developed as a continuum of observations from the watershed to the open ocean; account for connectivity with contaminant sources; be integrated into the IOOS "national backbone", and assure data quality and integrity.

Implementation of the National Water Quality Monitoring Network will assure access to real-time *continuous* observations over a broad geographical area, and will facilitate the acquisition and efficient dissemination of quality-assured data. Only then will it be possible to improve the scientific basis and effectiveness of coastal and ocean resource use decisions. It is anticipated that complementary data from the National Water Quality Monitoring Network and the Integrated Ocean Observing System will be essential for:

- Describing current conditions and detecting trends in system attributes that might impair sustainable use of coastal and estuarine resources;
- Linking human activities and resource use to changes in coastal and estuarine water quality, including delivery of freshwater to the estuaries;
- Relating contaminant and nutrient flux measurements to their ecological and human health impacts;
- Assessing impacts of habitat losses and modifications on biotic integrity, biodiversity and ecosystem productivity; and
- Enhancing numerical modeling and ecological forecasting capabilities to evaluate pollution source control and mitigation scenarios.

To address these considerations, and bring as many stakeholders to the table as possible, a coordinated Workshop ***Linking Elements of the Integrated Ocean Observing System (IOOS) with the Planned National Water Quality Monitoring Network*** was hosted by NOAA and the New Jersey Sea Grant College Program, and other partners on 19-21 September 2005 at Rutgers University. The overarching goal of the effort was to develop a Regional Pilot for water quality monitoring (physical, biological and chemical parameters) that linked IOOS product development to integrated coastal zone management (ICZM), and the health of coastal ecosystems. Parameters of interest included toxic chemicals, pathogens, "emerging" chemicals, nutrients, DO, harmful algal blooms (HAB), eutrophication, freshwater delivery, habitat loss/alteration, and biological response indicators.

The regional pilot was designed to provide integrated sampling coverage in coastal and estuarine waters as well as upland ("upstream") areas to promote comparability and transfer value of monitoring results. Specific outcomes of the workshop are summarized herein including the identification of:

- Key water-quality/quantity and ecosystem health related issues in the Mid Atlantic Coastal Ocean Observing Regional Association (MACOORA) Sub-Region including Delaware Bay;
- Overarching management questions that need to be addressed by the National Water Quality Monitoring Network (NWQMN) in concert with the evolution of the regional IOOS infrastructure;
- Current infrastructure and monitoring programs for addressing management issues in the MACOORA sub-region;
- Information “gaps” in the current monitoring framework;
- The scope and constituents of the federally-funded backbone of critical stations and measurements in order to assess long-term trends in water quality and condition of the coastal environment; and
- New technologies and measurement techniques that can improve the quality and timeliness of monitoring data type, acquisition and delivery.

We hope you find this Workshop Proceedings useful. Any feedback you wish to provide would be gratefully appreciated. Thank you.

Peter M. Rowe, Ph.D.
New Jersey Marine Sciences Consortium
New Jersey Sea Grant College Program

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Michael P. Weinstein, Ph.D.
New Jersey Marine Sciences Consortium

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FOREWORD

In its report entitled Ocean Blueprint for the 21st Century, the U.S. Commission on Ocean Policy recommended steps to design a National Monitoring Network (Chapter 15), achieve a sustained Integrated Ocean Observing System (Chapter 26), and modernize ocean data and information systems (Chapter 28). These systems and capabilities are viewed as essential for acquiring and managing data that will ultimately protect people and property, improve understanding of the health of coastal and oceanic ecosystems, forecast and documents effects of climate change and extreme natural events on the coastal environment and resources, and promote the sustainable use coastal resources and amenities. The coastal component of IOOS and the National Monitoring Network would be comprised of sensors and field measurements that are designed to collect data from the coastal watersheds to the open ocean with sufficient resolution to detect spatial and temporal trends, and help assure accountability for management decisions.

The development of a National Water Quality Monitoring Network is included in the U.S. Ocean Action Plan as part of the mandate to advance the Nation's understanding of the oceans, coasts, and Great Lakes.

> *The [NWQM] Network design will address and integrate watershed, coastal waters, and ocean monitoring based on common criteria and standards. In addition, it will provide information on water quality that, when interpreted with other information such as economic and land use data, will provide relevant scientific information to assist resource management and decision making. The network design will identify the major overarching management questions that need to be addressed and the fundamental elements of this national monitoring network, emphasizing the "Federally funded backbone [IOOS]" of water quality [and other sensor] networks and programs.*

Using these "marching orders" as a frame of reference, several state, federal and academic organizations convened to plan a three day workshop entitled: ***Linking Elements of the Integrated Ocean Observing System (IOOS) with the Planned National Water Quality Monitoring Network (NWQMN)***. Participants included NOAA, New Jersey Sea Grant, USGS, Rutgers University and the Mid-Atlantic Ocean Observing System Regional Association (MACOORA). In addition to federal and state agency personnel, stakeholders were drawn from a wide breadth of interests including academia, industry, municipal government, non-governmental organizations and environmental groups. Needless to say, the exchanges were lively, and it was the intent of the workshop organizers to capture the comments and interests of all parties in the design of a proposed pilot program. Hopefully, the consensus achieved, as well as the disparate points of view expressed were captured relatively effectively in these pages. It is important to note however, that this Proceeding represents just a *single* gathering of coastal stakeholders on coastal issues, and the reader is encouraged to go far afield to capture the viewpoints of others. Further information on these and other topics may be perused at the following URLs:
www.oceancommission.gov; http://ocean.ceq.gov/actionplan.pdf; www.macoora.org; http://oceans.ceq.gov/about/jsost_workshop/welcome.html; http://www.pewoceans.org; http://water.usgs.gov/wicp/acwi/monitoring; http://www.ocean.us; http://www.act-us.info

A COASTAL OBSERVATORY IN THE 21ST CENTURY – THE RUTGERS UNIVERSITY EXPERIENCE

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ABSTRACT

In concert with academic and industrial partners, Rutgers University, New Brunswick, New Jersey has developed a Mid-Atlantic coastal shelf ecosystem observatory that combines ocean surface satellite imagery and HF radar with subsurface autonomous vehicles and cabled observatories to provide comprehensive information about the water column overlying the continental shelf. Controlled by a centrally located operations center, the system is readily accessible to regional faculty and students for both research and teaching. After a decade at sea, the cabled network has been undergoing extensive upgrades to facilitate system integration into the national broader “backbone” of national ocean observing assets.

INTRODUCTION

In the past two centuries, the world’s oceans have undergone transformations due to massive in flux of nutrients and contaminants, increased fishing pressures, and introduction of exotic species, all of which result from human activities and population growth. The long-term impacts of these factors on the chemistry of continental shelves have oftimes been catastrophic, leading to loss or reductions in major fisheries, production of green house gases that alter climate regimes and food webs, and reductions in marine biodiversity that affect ecosystem resiliency. It is not surprising therefore that the U.S. Commission on Ocean Policy cited the need for “sound science for wise decision-making” to ensure the sustainable use of coastal resources for this and future generations. The Commission also highlighted the need for, “a robust infrastructure of cutting edge technology that forms the backbone of modern ocean and coastal science and effective resource management and enforcement”. Against this backdrop, the Rutgers Coastal Ocean Observing Laboratory (COOL) was created. Here we summarize the present status of the COOL and its long term effort to bring new observational technologies to the field of coastal oceanography. We will also highlight how the system fulfills many of the needs highlighted by the U.S. Commission on Ocean Policy.

LEO-15 Coastal Cabled Observatory

The Long-term Ecosystem Observatory (LEO-15) was originally constructed as a 10 km long fiber optic cable buried in the substrate and connected to the Rutgers Marine Field Station (RUMFS) near Tuckerton, New Jersey. In 1996, science Nodes A and B (Figure 1) were deployed in 15 m of water, located 8.1 and 9.6 km, respectively, offshore (Schofield et al., 2002;

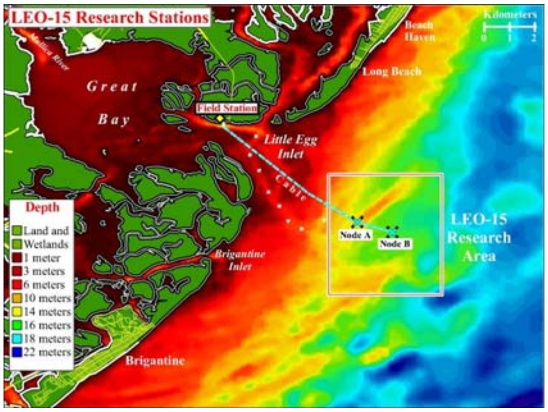


Figure 1. The Leo-15 cable route.

von Alt and Grassle, 1992). LEO-15 system has served the scientific community for well over a decade (Gargett et al., 2004; Oliver et al., 2004; Olson et al., 2003; Traykovski et al., 1999), with most of the initial program goals having been achieved (Table 1). The general public, and pre-collegiate educational programs, have also utilized the data (Crowley et al., 1998; Grassle et al., 1998). In the process, many lessons have been learned (Schofield and Glenn, 2004; Glenn and Schofield, 2003; Munk, 2000).

In 1998-2001, a series of month-long summer experiments were conducted in the vicinity of the LEO-15 to better understand the influence of alongshore topographic variations on coastal upwelling, and the latter's effect on phytoplankton distributions, and dissolved oxygen concentrations (Figure 2; Table 2). In addition to direct inputs, LEO-15 data were supplemented with remote sensing information from satellites, aircraft and shore based HF Radars, a cross-shelf mooring array of sensors, and the deployment of numerous research vessels and autonomous underwater vehicles. Nearly 200 researchers from over 30 institutions participated (Glenn and Schofield, 2003; Schofield et al., 2002). Operation of the system required radical collocation of scientists and technicians to the Rutgers coastal facilities making the system difficult to sustain for prolonged periods. However, the overall success of the program demonstrated the utility of integrated ocean observations into widespread use by the scientific community and beyond.

Table 1. The Desired Goals for Leo-15

1) Continuous observations at frequencies from seconds to decades, 2) Spatial scales of measurement from millimeters to kilometers, 3) Practically unlimited power and broad bandwidth, two way transmission of data and commands, 4) An ability to operate during storms, 5) An ability to plug in any type of new sensor and to operate them over the Internet, 6) Bottom mounted winches cycling instruments up and down in the water, either automatically or on command, 7) Docking stations for a new generation of autonomous (robotic) underwater vehicles (AUVs), 8) An ability to assimilate node data into models and make three-dimensional forecasts for the oceanic environment, 9) Means for making the data available in real-time to schools and the public over the Internet, and 10) Low cost relative to the cost of building and maintaining manned above- and below-water systems.

The Rutgers University Coastal Ocean Observation Laboratory (COOL)

To elevate coastal observations beyond the relatively short-term technologies tested at LEO-15, Rutgers University, in partnership with academic and industrial concerns, incorporated existing and new satellite imagery, high frequency radar (CODAR), autonomous underwater vehicles ("gliders") and new underwater cable systems into a shelf wide observatory capable of sustained year-round operations. The primary goal of the new observatory was to provide scientists with *sustained*

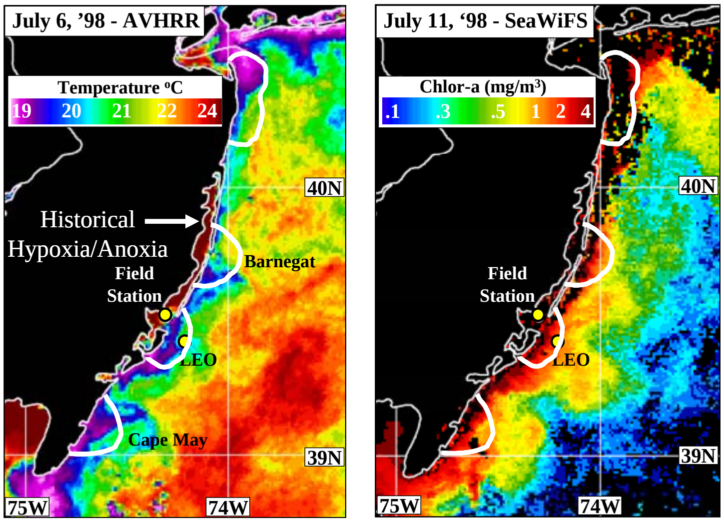


Figure 2. The science focus for the Leo experiments. *The white outlines denote regions where there is a high probability to find low dissolved oxygen in bottom waters. These regions are co-located with favored regions of upwelling (note the low temperatures measured by the AVHRR satellite) and corresponding high phytoplankton productivity (note high chlorophyll a values seen by the SeaWiFS satellite). LEO is in one of the low DO zones.*

datasets at ecologically relevant spatial and temporal scales. The need for sustainability required an operational model based on virtual collocation rather than the traditional, but inefficient radical collocation approach. Implementation began with the installation and testing of the first U.S. east coast long-range CODAR HF radar system in 2000. Other key milestones accomplished in the past three years included the development of reliable global satellite communications with the remotely operated underwater vehicles, installation of a new satellite receiver, and the upgrade of LEO-15.

Most critical was the establishment of a cost-center featuring a centralized observatory control room on Rutger's Cook College campus known as the Coastal Ocean Observation Laboratory (COOL).

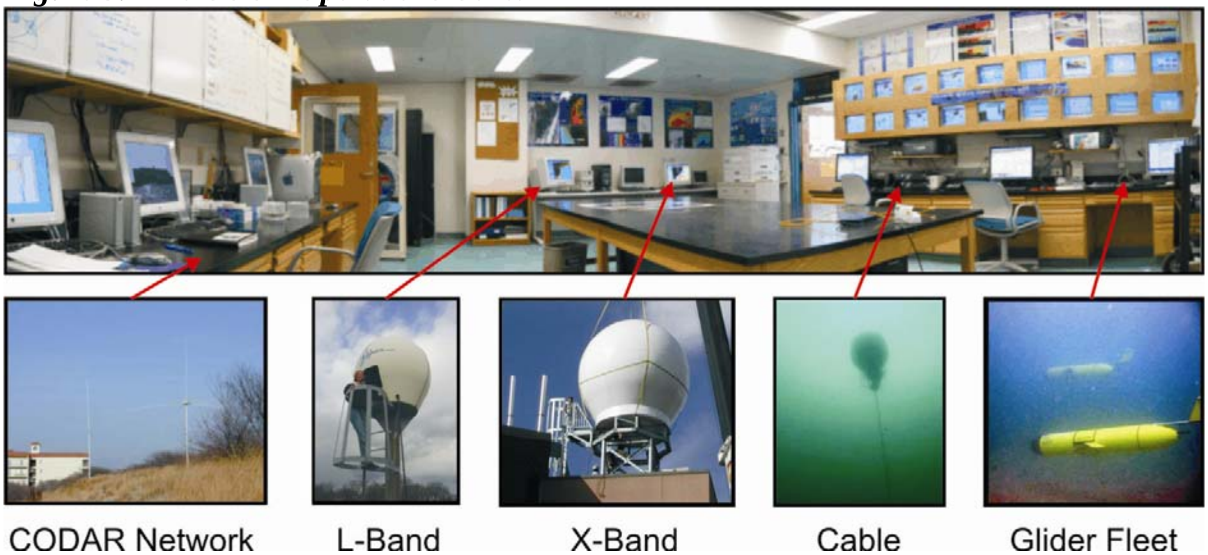
The COOL Operations Center

The COOL Operations Center (Figure 3) maintains the world's most advanced coastal ocean observatory with start-of-the-art capabilities that are continuously upgraded and transitioned into the system as new technologies come on line. The mission of the Center is to sustain operation of key observing technologies for scientific research, technology development, and education/outreach. Under the leadership its Director, COOL staff are responsible

Table 2: Goals of the LEO-15 Experiments

1) Build an observation network using *in situ* modern remote sensing and meteorological instrumentation;
2) Develop the ability to process, visualize and combine diverse datasets to generate real-time ("nowcasts") of 3-dimensional ocean structure;
3) Develop a new circulation model with multiple turbulence closure schemes and improved boundary conditions, obtained through coupling to atmospheric models, large-scale ocean models, and surface wave models;
4) Assimilate multivariate datasets into the ocean models in real time to generate nowcasts and forecasts of the 3-dimensional ocean structure;
5) Develop adaptive sampling strategies that use the nowcasts and forecasts to guide ship-towed and autonomous underwater vehicles for interdisciplinary research applications;
6) Develop an open-access database management structure for broad distribution of data, nowcasts and forecasts; and
7) Provide scientists with a user-friendly data-rich environment to support focused research.

Figure 3. The COOL Operations Center



for maintaining system hardware and software to ensure the real time acquisition, processing and generating real-time visualizations for the web, establishing and implementing QA/QC procedures, maintaining quality controlled archives. Cost-effective sustained spatial sampling of the coastal ocean is accomplished by: (1) local acquisition of satellite imagery from thermal infrared and ocean color sensors (Figure 4); (2) surface current and wave mapping with HF radar (CODAR) (Figure 5); (3) deploying autonomous underwater gliders equipped with physical and optical sensors, and (4) generating water column time series from a cabled observatory. Raw data are shared with users throughout the U.S. for real-time backup, data archiving, and advanced product generation. Each of these technologies provides long-term, synoptic scale data that are an invaluable asset for researchers conducting process studies within the region.

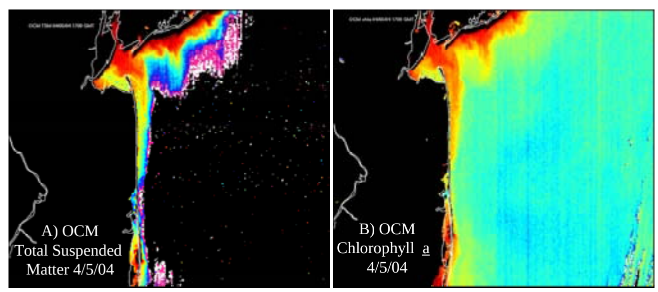


Figure 4. Imagery of the Hudson River plume

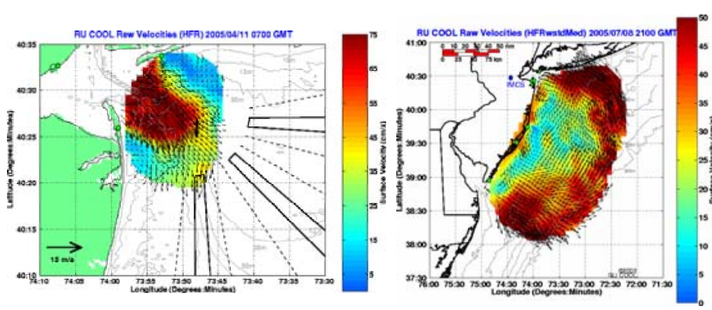


Figure 5. Surface current measured by HF radar. The panel on the left is a map showing the outflow of the Hudson river plume. The right panel shows the response of the shelf during a strong winter storm.

System Components
<u>SeaSpace Satellite Acquisition</u>

COOL operates both L-Band and a larger X-Band satellite tracking and data acquisition system that allows local real-time access to an international constellation of polar orbiting satellites. The L-Band currently tracks NOAA's Polar Orbiting Environmental Satellites (POES) and China's FY1-D satellites that provide Sea Surface Temperature (SST), visible and simple ocean color data. The X-Band is used to acquire high resolution spatial and spectral data from more recently deployed satellites such as NASA's MODIS (both Terra and Aqua) and India's Oceansat. By accessing satellites operated by other countries, the system offers the advantage of decreased revisit intervals, and provides multiple overflights of rapidly evolving coastal features at different times of day. Missing data (e.g., due to ground station downtime) are minimized through a cooperative agreement with the University of Maine that allows either system to write recently acquired raw data to the other's software if it senses a disruption. This backup enables the downstream data flow to continue uninterrupted at either location.

<u>CODAR HF Radar Network</u>

CODARs are compact HF radar systems that provide current mapping, wave monitoring and vessel tracking capability. COOL currently owns and operates over a dozen individual CODAR HF radars deployed in three nested multi-static networks in the New York Bight region. Multistatic operation, enabled by GPS-based synchronization, has the advantage of allowing a radar receiver to acquire signals from any radar transmitter within range. This increases both the coverage area and the accuracy of the derived current fields. The long range 5 MHz network is deployed on New Jersey's coast and at the island of Nantucket providing coverage of the regional continental shelf out beyond the shelf break. The intermediate range 13 MHz and high-resolution 25 MHz networks are deployed around the entrance to New York Harbor, and the entrance to and within New York Harbor, respectively. In addition to the usual shore based systems, COOL operates buoy-based bistatic transmitters, one at a larger spar buoy for 5 MHz and, the second on a smaller surface buoy for the 25 MHz transmitter. The transmitters are paired with an onshore receiver, extending coverage offshore and improving the accuracy of total vector current measurements near shore. Recently, the system has been upgraded by the installation of a compact super-directive receiver at 13 MHz to increase range and directivity, and 2006 will inaugurate the construction of a 13 MHz bistatic transmitter buoy.

<u>Glider Fleet</u>

Gliders are autonomous underwater vehicles that propel themselves along predetermined transects by changing their buoyancy and by using accessory planes (wings) to glide in "saw tooth" pattern through the water column. At user specified intervals, the glider surfaces, transmits data to shore, and checks its messaging system for new directives and/or missions. To date, the gliders have logged over 15,000 km of transect deployment in the New York Bight, and at offshore locations in Massachusetts, Virginia and Florida, Sargasso Sea, Baltic Sea, Irish Sea, Mediterranean and Australia (Figure 6). Sensors on the gliders include a CTD, and a payload bay capable of carrying a variety of optical sensors, a Scattering Attenuation Meter (SAM), and optical pucks. A mission control specialist monitors glider performance on each mission and alerts operators of any problems. Artificial Intelligence (AI) is being added to the mission control center using a programming approach similar to NASA's "intelligent spacecraft" system.

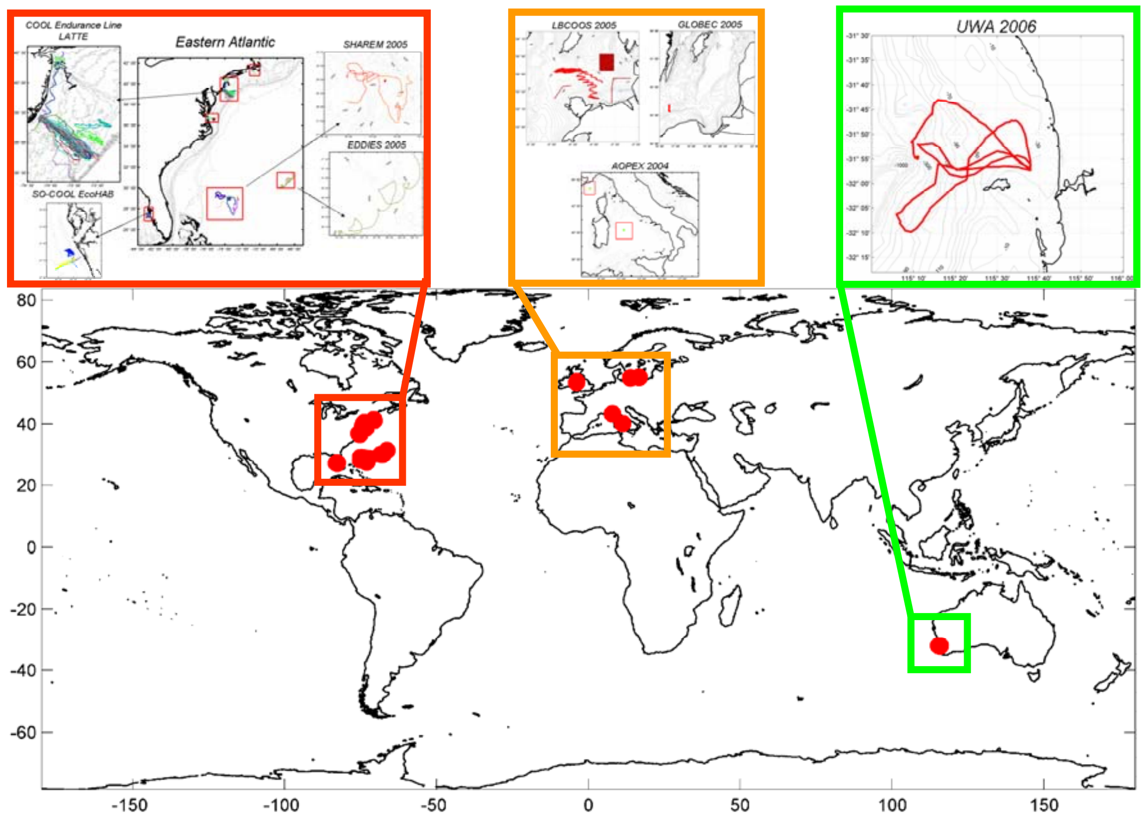


Figure 6. Global deployments of Webb Sloccum Gliders. The Gliders are controlled during their missions from the COOL Operations Center in New Jersey.

<u>Coastal Cabled Observatory</u>

Rutgers University recently initiated a partnership with industry to rebuild the LEO-15 cabled observatory to address key needs (Table 3; Figure 7 a-e). The upgrades include 15 new science and six video interfaces. The new communication system is implemented as a local area network (LAN) using Internet Protocols (IP) over a 1000BASE-TX GB Ethernet. A new power system is designed to reduce the effects of summer shore voltage brownouts, and all power ports are independently and dynamically configurable without affecting other ports. A DACNet R4 ocean observatory operating system was installed to control and monitor node infrastructure and instruments. By providing remote access over the Internet, the system provides full remote control capability at COOL.

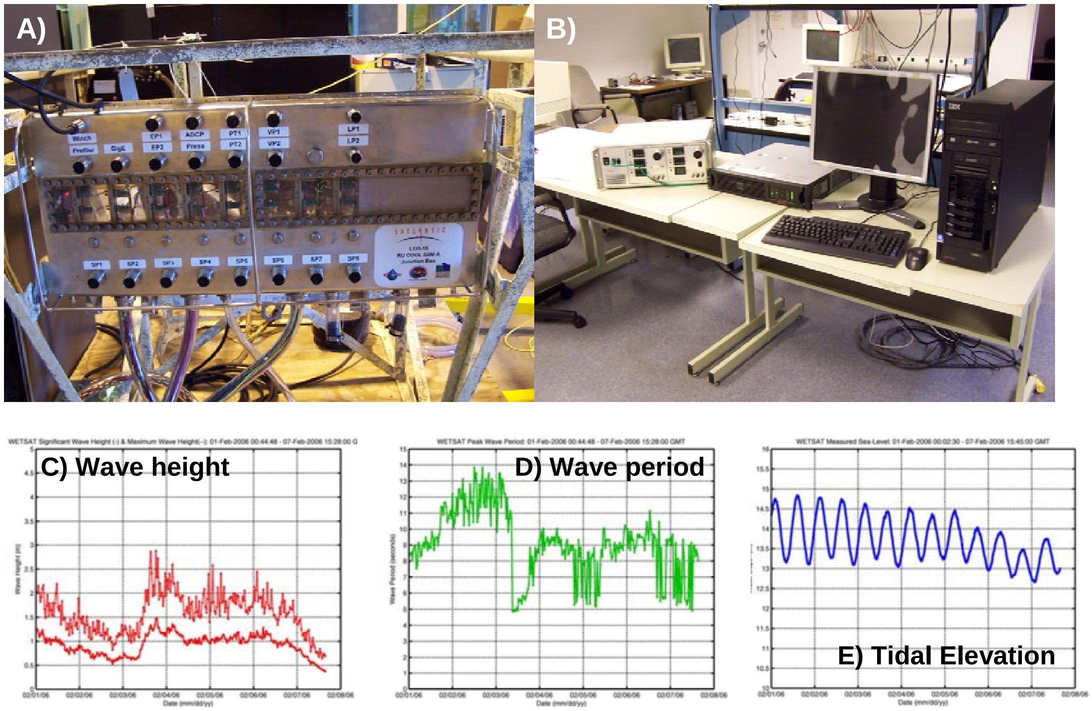


Figure 7. The upgraded LEO system. *A) The subsurface node of LEO. B) The shore-based control network. C-E) Initial data collected with the new LEO system.*

Table 3: Key needs identified for the LEO-15 Coastal Cabled Observatory upgrade.

1) Upgrade a single node while allowing the second node to operate on as much of the existing infrastructure as possible;
2) Modularize hardware to improve reliability and serviceability;
3) Separate the winched system as an independent and easily recoverable, serviceable and ultimately replaceable unit;
4) Update the communication standards to a post-WWW environment;
5) Improve power control to individual sensors and systems;
6) Provide a larger number of simple interfaces between new sensors and the permanent infrastructure,
7) Increase the video capabilities to allow for improved control and recording,
8) Install upgradeable control software;
9) Provide a means for moving the cable control interface to an offsite control center; and
10) Provide a shore-based simulator to test sensors before deployment.

CONCLUSIONS

The field of oceanography and the tools oceanographers use are maturing, prompting and enabling more collaborative and interdisciplinary research as well as economically vital applications. As this process evolves, policy decisions on the safe and sustainable use of our coastal oceans will increasingly depend on scientific knowledge of the environment to improve both prediction and our understanding of the “downstream” consequences of our actions. Improved predictions for decision making requires sustained observations to continuously update the present knowledge of the environment, and continued scientific research to improve our understanding of the processes that control how environmental baselines will be affected in the future. As the field matures, additional effort will be required to train a new generation of technology proficient operational oceanographers to sustain the observatories, and to educate the broader public on the linkages between the ocean and a sustainable future.

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THE USEPA NATIONAL COASTAL ASSESSMENT AND COASTAL CONDITION REPORT – A SUMMARY

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ABSTRACT

To meet the need for a national program that rigorously assesses coastal ecosystem health and condition, the United States Environmental Protection Agency (USEPA) has implemented the National Coastal Assessment (NCA), a study designed to evaluate methods to advance the science of ecosystem condition monitoring. The approach is based on an integrated, comprehensive monitoring program developed in partnership with the coastal and Great Lakes states. This compatibility allows regional compilation of data so that a 'report card' for health of the Nation's coastal waters as a whole can be issued. To date, two National Coastal Condition Reports (NCCR) have been issued, with the most recent report (NCRR II) including assessments of 100 % of the nation's estuaries in the contiguous 48 states and Puerto Rico. As a result of this effort, USEPA determined that the overall condition of the nation's coastal waters was at best fair, based on five key indicators of ecological health: water quality, coastal habitat loss, sediment quality, benthic community condition, and fish tissue contaminants. Consistent with the recent US Commission on Ocean Policy report, the NCRR sends a clear message about the serious challenges facing our nation's oceans and coastal resources.

INTRODUCTION

By the middle of this century, approximately 75% of the nation's population will live within 80 km (50 miles) of the coast. Nine out of ten of the largest cities in the world are on seacoasts, several in the United States yet the coastal zone is only about 11% of the land surface. US coastal areas are also the destination for 180 million visitors yearly; and international trade is expected to nearly triple over the next two decades, with more than 90% of this trade waterborne and requiring larger ports and services. New pressures on watersheds and coastal resources will result from increased competition for living space, and the conflict that often arises between humans and their environment. More than ever, sustainability will depend on striking an elusive balance between economic growth and stewardship of natural resources (Weinstein and Reed 2005; US Commission on Ocean Policy 2004; Weinstein 2006).

Coastal industries contributed more than $150 billion to the national economy in 1995, the most recent year when statistics were available. One out of every six jobs in the United States is linked in some fashion to the nation's estuaries and oceans - - ports commerce and maritime trades, coastal tourism, marine technology, and fisheries and aquaculture (National Ocean Conference 1998). Until recently, however, the US coastal zone has been viewed as a "commons" with infinite capacity to serve the nation's needs. That perception has changed, and most scientists and managers now agree that the commons is being taxed to its very limits! Our future success will rest in managing coastal resources in a matrix of ever expanding human influence in the coastal zone, especially the land water interface where some of the highest levels of coastal productivity are measured.

A Question of Balance

Humans use coastal embayments and the shore zone for activities that may be, and indeed frequently are, in conflict. In the next century, managing for growth will require proactive public involvement and greater awareness of the issues. Restoring ecosystem health to our coastal waters, therefore, requires not only consideration of ecosystem components (including watersheds), but also the continued vitality of the nation's coastal economy. We can and must have both. Along with research to better understand system function, a determination of baseline conditions and a monitoring program with sufficient statistical power to detect change in a reasonable period are necessary prerequisites to successful management of the nation's coastal resources. When these prerequisites are met, science based policy becomes a reality, and best management practices can be implemented with confidence.

National Coastal Assessment Program

To meet the need for a program that rigorously assesses coastal ecosystem health and condition, the United States Environmental Protection Agency (USEPA) has implemented the National Coastal Assessment (NCA) program. The effort is designed to evaluate methods to advance the science of ecosystem condition assessment through an integrated, comprehensive monitoring program in partnership with the coastal states. The aforesaid compatibility allows regional compilation of the data so that a 'report card' for the nation's coastal waters as a whole can be issued.

For the NCA on the Atlantic Coast, sampling populations were designated as estuarine waters of the Atlantic seaboard; i.e., the area between head of tide and articulation with the Atlantic Ocean. These waters included small stream subestuaries that connect to larger embayments or sounds.

PROJECT GOALS AND OBJECTIVES (TASKS)

There is great compatibility between USEPA and the state agencies in shared goals for monitoring and improving the condition of the regions' coastal waters. This is as it should be, given the desire by most agencies to approach coastal monitoring as a cooperative venture. The USEPA's Environmental Monitoring and Assessment Program (EMAP) was a first step, but the NCA has the potential to achieve even greater integration of state and federal programs.

Specific objectives for the NCA are to collect water; sediment and biological samples in accordance with recommended USEPA procedures within each sampling array (USEPA 1995, NOAA 1998; Heitmuller, T. and J. K.Summers 2000):

- Use polygonal sampling grids for each of the waterbodies investigated designated as: 1) open waters of the mainstem and shoals from the estuary mouth to the head of tide; and 2) all major tributary subestuaries;
- Randomly assign three sampling locations to each polygon;
- Randomly select one of the three (3) stations in each polygon as the primary location for each sampling event;
- Establish a seasonal sampling window, generally at the time of maximum biodiversity in the system each year;
- At each sampling location (Table 1):
- measure routine water quality and light attenuation;
- collect sediments for measuring contaminant concentrations (metal and organics), TOC, toxicity (bioassays), percent silt/clay and macrobenthos;
- At each sampling station conduct a 10 min tow with an otter trawl to collect nekton for community structure and tissue analyses;
- Qualitatively characterize the area around each sampling station for marine debris (presence/absence), dominant vegetation (SAV, macrophytes, macroalgae), substrate type and physiographic setting (harbor, tidal creek, tidal flat, etc.);
- Conduct QA/QC analyses on a subset of the data in accordance with established USEPA procedures, and;
- Prepare a data report that will be used to create a "snapshot" of existing conditions (physico/chemical and biological) in each waterbody.

Table 1. NCA CORE INDICATORS

WATER QUALITY INDICATORS

Hydrographic Profile
- -dissolved oxygen
- -salinity
- -pH
- -temperature
- -depth
- -light attenuation
- -secchi depth

Water Quality
- -dissolved nutrients
- -chlorophyll-a
- -total suspended solids

Sediment Quality Indicators
- - contaminants
- -TOC
- -toxicity (bioassays)
- -percent silt/clay

BIOTIC INDICATORS

Nekton
- -community structure
- -tissue contaminants
- -external pathology

Macrobenthos
- -community structure

QUALITATIVE HABITAT INDICATORS
- -SAV
- -habitat type
- -marine debris

Project Approach

To the extent practicable, existing state agency sediment and biological sampling stations were incorporated into USEPA's final allocation of sampling stations within each sampling grid (polygon). Prior to undertaking the NCA, a Standard Operating Procedures (SOP) Manual was prepared that ensured consistency in sampling approach and methods. The SOP Manual adopted procedures provided by USEPA to assure consistency in sample collection and processing (Strobel 2000).

Quality Control/Quality Assurance

The USEPA's *Quality Assurance Project Plan* (Heitmuller, T. and J.K. Summers 2000) was adopted as the guiding framework for all project activities.

NATIONAL COASTAL CONDITION REPORT II (NCCRII)

USEPA issued the second of its series of environmental assessments of U.S. coastal waters and the Great Lakes in January 2005. The updated report included assessments of 100 percent of the nation's estuaries in the contiguous 48 states and Puerto Rico.

The NCCRII is based on data gathered by a variety of federal, state and local sources, and includes over 50,000 samples taken between 1997 and 2000 in all continental seacoasts and Puerto Rico. Three categories of data were analyzed: coastal monitoring data, offshore fisheries data, and assessment and human health advisory data.

What is the Overall Condition of the Nation's Coastal Waters?

As a result of this effort, USEPA determined that the overall condition of the nation's coastal waters was fair, essentially the same conclusion reached in 2001 (USEPA 2001). This rating was based on five key indicators of ecological health: water quality, coastal habitat loss, sediment quality, benthic community condition, and fish tissue contaminants. For each indicator, a score of good, fair, or poor was assigned to each coastal region of the U.S. Ratings were then averaged to create overall regional and national scores as illustrated below using "traffic light" coloring (Figure 1). Consistent with the recent US Commission on Ocean Policy report (*www.oceancommission.gov*), the NCRR sends a clear message about the serious challenges facing our nation's ocean and coastal resources.

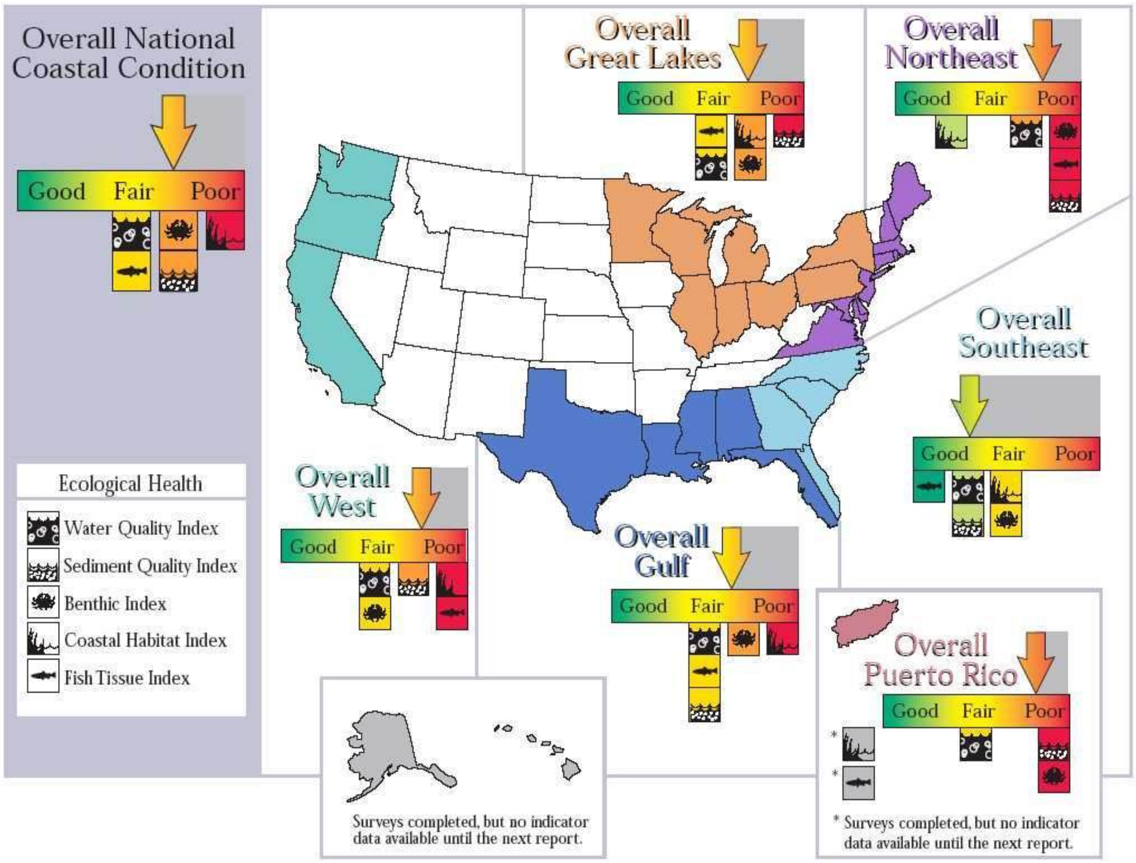

Figure 1: Overall national and regional coastal condition between 1997 and 2000.

Changes from the Last Report

The first NCCR, published in 2001, also reported that the nation's estuarine resources were in fair condition. This report used available data from 1990 to 1996 to characterize about seventy percent of the nation's estuarine resources. The total number of indicators was reduced in the second report from seven to five. Moreover, the eutrophication index, dissolved oxygen, and water clarity indicators from the earlier NCCR were consolidated to form a single water quality index. As a result, the new water quality index better reflects the triad between water quality, sediment quality, and living resource indicators. Comparisons between the two Coastal Condition Reports are not straightforward because of these and other changes. An indirect benefit of the current report has been to build local, state,

Our Treasured Coastal Waters

- ***Coastal habitats provide spawning grounds, nurseries, shelter and food for finfish, shellfish, birds and other wildlife, as well as nesting, resting, feeding, and breeding habitat for 85 percent of waterfowl and other migratory birds.***
- ***Estuaries provide habitat for more than 75 percent of America's commercial fish catch, and for 80 to 90 percent of the recreational fish catch.***
- ***In 2001, commercial fishermen landed 9.8 billion pounds of fish and shellfish valued at $3.3 billion.***
- ***Nationwide, commercial and recreational fishing, boating, tourism, and other coastal industries provide more than 28 million jobs. Coastal recreation and tourism generate $8 billion to $12 billion annually.***

and tribal capacity in cost-effective and scientifically sound monitoring of local conditions required under the Clean Water Act.

SUMMARY OF OTHER FINDINGS

Other findings of the nationwide analysis in the NCRR may be summarized as follows:

- From a regional perspective, the coastal condition in the Southeast is good, Gulf of Mexico and the West is fair, the Great Lakes is fair to poor and the Northeast and Puerto Rico is poor. Future reports will assess regional trends for the majority of the U.S. coastal waters.
- Nationally, twenty-one percent of assessed resources are unimpaired; thirty-five percent are impaired; forty-four percent are threatened for aquatic life use or human use.
- Suitability of waters for fishing is measured using the fish tissue contaminants index. Twenty-two percent of coastal waters are impaired for fishing, based on USEPA's guidelines for moderate consumption of recreationally-caught fish.
- Suitability of waters for aquatic life use is measured using the water quality, sediment quality, habitat loss, and benthic indices. Twenty-eight percent of coastal waters are impaired for aquatic life use.
- Among the key indicators, coastal habitat condition, sediment quality, and benthic condition ranked the lowest; whereas, individual components of water quality, including dissolved oxygen and dissolved inorganic nitrogen, ranked slightly better.

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WATER-QUALITY MONITORING IN WATERSHEDS ABOVE THE HEAD OF TIDE IN THE DELAWARE RIVER BASIN

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ABSTRACT

Extensive water-quality data, including physical characteristics and concentrations of chemical and biological constituents, are collected in watersheds above the head of tide in the Delaware River Basin (DRB) by various groups. A table and summary of monitoring by Federal Agencies and the Delaware River Basin Commission (DRBC) in various hydrologic compartments are described. As a result of the diverse monitoring and data storage by these groups, however, assembling data to determine sources, loads, and environmental effects of contaminants in watersheds above the head of tide, estuaries, and coastal zones of the DRB is difficult. During a breakout session at the IOOS-NWQMN Workshop at Rutgers University, recommendations to enhance water-quality monitoring and data storage for the DRB include improved coordination and documentation of monitoring methods and a centralized data exchange among agencies.

INTRODUCTION

The DRB encompasses approximately 13,500 square miles in parts of four states, and includes 216 tributaries that feed the Delaware River (Figure 1). A report by the DRBC on water-quality monitoring and assessment in the Delaware River and Bay describes several concerns, including assuring that adequate data are available to assess the quality of water in the Delaware River in order to implement the DRBC's water-quality programs. Other issues include defining the current water quality of the Lower Delaware River; maintaining current water quality in the DRB, and identifying natural background conditions (DRBC, 2004).

Extensive water-quality data, including physical characteristics and concentrations of chemical and biological constituents, are collected in watersheds above the head of tide in the DRB by various groups including the DRBC; Federal, State, and local agencies; universities; watershed associations; volunteer groups; and the private sector. The DRBC collects a variety of water-quality data as part of its own monitoring programs, and also solicits available data from the Basin States in order to assess water quality in the Delaware River and Bay (DRBC, 2004). Monitoring programs above the head of tide coordinated by the DRBC include the Scenic Rivers (SRMP) and the Lower Delaware (LDMP) Monitoring Programs. The SRMP extends north of the Delaware Water Gap and the LDMP covers the area from below the Water Gap to the head of tide at Trenton. As a result of the diverse monitoring and data storage by these groups, however, assembling data to determine sources, loads, and environmental effects of contaminants in watersheds above the head of tide to estuaries and coastal zones is difficult.

In order to estimate loads of contaminants from watersheds to estuaries and ultimately to oceans, it is necessary to monitor concentrations and rates of transport of contaminants in all parts of the hydrologic cycle in watersheds above the head of tide. Water compartments in the hydrologic cycle above the head of tide include the atmosphere, ground water, wetlands, and surface water. Surface water includes streams, rivers, lakes, and reservoirs. In addition, soils and sediments (suspended and streambed) can be substantial sources of contaminants to surface water and estuaries. Nonpoint and point sources of contamination affect the quality of water in a watershed. Generally, contaminants from human activities that are released to the atmosphere or the land surface are transported from ground water or by overland flow to tributaries that discharge to the Delaware River, directly to the Delaware Estuary, or to the Atlantic Ocean.

Figure 1. The Delaware River Basin

EXISTING REGIONAL MONITORING PROGRAMS

Federal water-quality-monitoring programs (Table 1) constitute the "backbone" of water-quality monitoring across the Nation and in the DRB. As part of these programs, data are collected by the U.S Environmental Protection Agency (USEPA), the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Fish and Wildlife Service (USFWS), the U.S. National Park Service (USNPS), and the National Atmospheric Deposition Program (NADP). USEPA also works closely with State agencies to develop statewide ambient surface- and ground-water-quality networks. In general, Federal agencies collect and analyze water samples consistently across the country; however, coordination among agencies may be absent and data generally are not comparable.

Atmospheric Deposition, Groundwater and Wetlands

Atmospheric conditions must be monitored during wet and dry conditions to estimate loads of contaminants deposited on the land surface or directly on surface water. Atmospheric monitoring (Table 1) is conducted as part of the National Atmospheric Deposition Program (NADP), which consists of the National Trends Network (NTN), AirMon, and the Mercury Deposition Network (MDN). In addition, atmospheric data are collected for the USEPA Clean Air Status and Trends Network (CASTNET). The amount and duration of precipitation must be monitored to measure wet deposition. Only three NADP and two CASTNET sites are in the DRB. Few sites are near estuaries or along coasts, where conditions may be different from those at inland sites. The types of constituents and characteristics monitored in atmospheric sources typically are pH, hydrogen ion, sulfate, nitrate, ammonia, calcium, magnesium, potassium, sodium, and chloride. Analyses of samples from these sites rarely include analyses for metals, pesticides, volatile organic compounds, or other contaminants from human activities, which are needed to estimate loads from atmospheric deposition.

Ground water is a substantial source of water and dissolved constituents to surface water. During a drought or low-flow conditions, almost all the water in a stream or river is derived from ground water—the exceptions being point-source discharges and dry atmospheric deposition. Ground water can be classified as being derived either from an unconfined or a confined aquifer. Unconfined aquifers near coastal areas may discharge water and contaminants directly to estuaries or to the ocean. Little is known about the quantities of contaminants discharged from ground water to estuaries. Federal and State ground-water-monitoring networks in the Delaware Basin include the USGS National Water Quality Assessment (NAWQA) Program and various State programs funded by USEPA and USGS. Water samples collected from ambient networks by the states four states in the DRB are analyzed for a broad spectrum of water-quality constituents, including nutrients, metals, volatile organic compounds, and pesticides; however, different sampling and analytical methods used by the States may make the data incomparable.

Wetlands typically are ground-water discharge sites and commonly are adjacent to surface-water bodies. Relatively little is known about the quality of water in freshwater wetlands. Wetlands commonly contain high concentrations of organic matter and can be sinks of contaminants from the atmosphere, ground water, and surface water. The National Wetlands Inventory maintained by the U.S. Fish and Wildlife Service contains monitoring data related to the characteristics, extent, and status of the Nation's wetlands (Table 1). Typically, the loss of wetlands over time is the only consistently available measurement, and information on the water quality and health of wetlands is scarce.

Table 1. Federal water-monitoring programs related to watersheds above the head of tide in the Delaware River Basin

[Atm, atmosphere; E, ecology; GW, ground water; N, nutrients; P, pesticides; V, volatile organic compounds; TE; trace elements; S, streamflow; SW, surface water; URL, Uniform Resource Locator; W, wetlands]

Agency and web-page URL Program and web-page URL	Abbre--viation	Type of monitoring	Program monitoring objectives related to the hydrologic cycle and water quality
U.S. Geological Survey (USGS) http://www.usgs.gov			
National Streamflow Information Program http://water.usgs.gov/nsip/	NSIP	S	NSIP consists of a core of USGS-funded and -operated streamgages, streamgages operated by the USGS but funded in cooperation with other agencies, and streamgages funded and operated by other agencies.
National Stream Quality Assessment Network http://www.usgs.gov/nasqan	NASQAN	SW	The major impetus for establishing the NASQAN program in 1974 was to develop a baseline water-chemistry data set that was long-term and systematically collected throughout the nation. NASQAN monitoring has been reduced drastically and no currently operated sites are in the Delaware Basin.
National Water Quality Assessment Program http://www.usgs.gov/nawqa http://nj.usgs.gov/nawqa/delr/	NAWQA	SW, GW, S, P, N, TE, V, E	The NAWQA Program is a primary source for long-term, nationwide information on the quality of streams, ground water, and aquatic ecosystems. The goals of NAWQA are to assess the status and trends of National water quality and to understand the factors that affect it. The Delaware River Basin has been a NAWQA basin since 1998. (http://nj.usgs.gov/nawqa/delr/)
Collaborative Environmental Monitoring and Research Initiative http://www.fs.fed.us/ne/global/research/drb/	CEMRI	SW, Atm	CEMRI includes monitoring by the USGS, USFS, USNFS, and other agencies as a prototype environmental monitoring strategy that will link air quality, hydrologic, and forestry information across the landscape of the Delaware River Basin.
U.S. Environmental Protection Agency (USEPA) http://www.epa.gov			
Clean Air Status and Trends Network http://www.epa.gov/castnet/	CASTNET	Atm	CASTNET is the primary source for data on dry acidic deposition which is used to evaluate the effectiveness of National emission control strategies.
National Atmospheric Monitoring Network http://www.epa.gov/oar/oaqps/qa/monprog.html	NAMS	Atm	The USEPA's ambient air quality monitoring program is carried out by State and local agencies and consists of three major categories of monitoring stations--State and Local Air Monitoring Stations (SLAMS), National Air Monitoring Stations (NAMS), and Special Purpose Monitoring Stations (SPMS). Additionally, a fourth category of monitoring station, the Photochemical Assessment Monitoring Stations (PAMS), which measures ozone precursors (approximately 60 volatile hydrocarbons and carbonyl) has been required by the 1990 Amendments to the Clean Air Act.
Environmental Monitoring and Assessment Program http://www.epa.gov/emap	EMAP	SW	EMAP is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of current ecological condition and forecasts of future risks to our natural resources.
Wadeable Streams Assessment http:// http://www.epa.gov.wsa	WSA	SW	The WSA is an ecological assessment of wadeable streams in the U.S. based on a stratified survey that will allow the extrapolation of stream condition in each ecological region of the U.S to streams for which no data are available. The objective is to provide a status report of the condition and health of wadeable streams.
U.S. Fish and Wildlife Service (USFWS) http://www.fws.gov			
National Wetlands Inventory http://wetlands.fws.gov	NWI	W	This NWI provides information on the characteristics, extent, and status of the Nation's wetlands and deepwater and other habitats.
U.S. National Park Service (USNPS) http://www.nps.gov			
Vital Signs http://science.nature.nps.gov/im/monitor/VitalSigns.cfm	VS	W, E	VS is designed to support USNPS's headquarters, regions, networks, and park-based managers and resource specialists by providing National consistency in the acquisition and management of water-quality information for park waters.

Table 1. Federal water-monitoring programs related to watersheds above the head of tide in the Delaware River Basin (continued).

[Atm, atmosphere; E, ecology; GW, ground water; N, nutrients; P, pesticides; V, volatile organic compounds; TE; trace elements; S, streamflow; SW, surface water; URL, Uniform Resource Locator; W, wetlands]

Agency and web-page URL Program and web-page URL	Abbre--viation	Type of monitoring	Program monitoring objectives related to the hydrologic cycle and water quality
Delaware River Basin Commission (DRBC) http://www.state.nj.us/drbc/			
Lower Delaware Monitoring Program http://www.state.nj.us/drbc/LD/index.htm	LDMP	SW, S	The LDMP includes monitoring of the Delaware River and its tributaries between Trenton, New Jersey, and the Delaware Water Gap.
Scenic Rivers Monitoring Program http://www.state.nj.us/drbc/04IntegratedList/surfacewater3.1.pdf	SRMP	SW	The SRMP has included monitoring above the Delaware Water Gap by the DRBC and the National Park Service since 1984. This area includes portions of the National Wild and Scenic Rivers System and many high-quality drainage systems in parts of New York, Pennsylvania, and New Jersey.
Other			
National Atmospheric Deposition Program/National Trends Network http://nadp.sws.uiuc.edu	NADP/ NTN	Atm	The NADP/NTN is a nationwide network of precipitation monitoring sites. The network is a cooperative effort among many groups, including the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, and other governmental and private entities. The purpose of the network is to collect data on the chemistry of precipitation for monitoring of long-term geographic and temporal trends.
AIRMon http://nadp.sws.uiuc.edu/AIRMoN/		Atm	AIRMon is designed to provide atmospheric data with greater temporal resolution than the NTN
Mercury Deposition Network http://nadp.sws.uiuc.edu/mdn	MDN	Atm	The objective of the MDN is to develop a National database of weekly concentrations of total mercury (Hg) in precipitation and the seasonal and annual flux of Hg in wet deposition. The data are used to develop spatial and seasonal trends in Hg deposited to surface water, forested watersheds, and other sensitive receptors.

Rivers and Streams

Rivers are the major source of water to estuaries. Average discharge at the head of tide at the Delaware River at Trenton gaging station over the period of record (1930-2004) is 11,730 cubic feet per second. In rivers and streams it is necessary that streamflow is measured at the time of sample collection and that representative samples are collected and composited across the stream channel. By measuring concentration and streamflow, the load of constituents and contaminants in the water can be estimated. Concentrations can vary considerably between base-flow and high-flow events. Grab samples collected from the bank of a stream or from bridges at the center of the stream most likely are not representative of the central tendency of the water-quality of the stream at the time of the sample collection. The streamflow of many streams and rivers in the DRB is monitored by the USGS as part of the National Streamflow Information Program (NSIP) (Table 1). Currently, 157 stream gages in the DRB are real-time platforms and can be accessed from the Internet. Historical records at many sites often are greater than 30 years. Methods used by other groups to measure stream discharge by other groups may not be consistent with USGS methods, or discharge may not be measured at all.

Monitoring at the USGS National Stream Quality Assessment Network (NASQAN) sites began in 1974 but has diminished over the years. Once the primary source of loading data from rivers to estuaries in the United States, more than 500 stations nationwide were sampled monthly for nutrients, major ions, and suspended sediment; in 1994, sampling occurred quarterly at about 275 stations. Currently, there are no NASQAN sites in the Delaware River Basin. In some cases, historical data are used to evaluate temporal trends in streamwater quality, but sampling methods and analytical minimum reporting levels have changed over time, and results of analyses are not comparable to those conducted more recently. This is especially true for trace-element analyses, as contamination from sampling equipment and/or atmospheric sources commonly resulted in elevated concentrations in the past. More recently, the USGS developed "ultra-clean" sampling procedures for trace-element and low-level organic analyses (Wilde and others, 1988; and Ivahnenko, and others, 2001).

As part of the USGS National Water Quality Assessment (NAWQA) Program, monitoring in the DRB was conducted from 1998 to 2001 (Table 1). Surface-water studies were designed to assess the effects of natural factors and human activities on stream chemistry and ecological communities. Ten streams were sampled from 1998 to 2001 at regular intervals and during storms to examine variations in water quality and biological communities over time. Stream surveys were conducted at more than 80 sites (sampled only once or twice) to describe the spatial distribution of contaminants and examine relations among land use, water quality, and biological communities. Bed-sediment and fish-tissue samples were collected throughout the basin to document the distribution of metals, organochlorine pesticides, industrial compounds, and semi-volatile organic compounds. A special study of mercury in water, sediment, and fish was conducted (Fischer et al., 2004). The minimum reporting levels (MRLs) for many of the organic compounds were on the order of parts per trillion and therefore are not comparable to results of other studies conducted in the basin. Most NAWQA surface-water sampling sites are on tributaries, and few are on the main stem of the Delaware River.

The Delaware River Basin Collaborative Environmental Monitoring and Research Initiative (CEMRI) is a combined effort among the USGS, the U.S. Forest Service (USFS), and the U.S. National Park Service (USNPS) to implement an environmental monitoring strategy that will link air-quality, hydrologic, and forestry information in the DRB (table 1). CEMRI links existing intensive ecological research and monitoring stations, regional surveys, remote-sensing programs, and fixed-site monitoring networks in order to track complex environmental issues at a range of spatial and temporal scales.

A USEPA Environmental Monitoring and Assessment Program (EMAP) (Table 1) project was conducted in the Maurice/Cohansey River Basin in 2001. Water, sediment, and fish-tissue samples were collected once from 120 sites in freshwater and tidal parts of streams. Sediment and tissue samples were analyzed for metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCBs) congeners, chlorinated pesticides, and total organic carbon. Sediments were analyzed for grain size and sediment toxicity. Water samples were analyzed for field characteristics (temperature, dissolved oxygen, pH, and salinity), nutrients, chlorophyll A, and total suspended solids. Biological analyses included benthic species composition, fish communities, and fish pathologies.

Real-time water-quality data are collected by the USGS at 34 surface-water sites in the DRB; 11 of these sites are on the main stem of the Delaware River as of 2006. Sensors typically include those that measure temperature, pH, dissolved oxygen, specific conductance (SC), and occasionally turbidity. These sensors provide a generalized picture of water-quality conditions on a continuous basis except during winter months, when frozen conditions limit their use at some sites. The SC sensors at various locations are used to estimate the variability of chloride concentrations in the estuary, especially near surface-water intakes for drinking water.

The USEPA Wadeable Streams Assessment (WSA) concentrates on ecological monitoring of small upland streams (Table 1). Monitoring for the WSA includes the determination of physical parameters such as a visual inspection of the stream bank and vegetation; chemical analyses to measure pH, dissolved oxygen, alkalinity, turbidity, dissolved inorganic and organic carbon, major ions, metals, nutrients, color, total suspended solids; and biological measurements of macroinvertebrate communities. The WSA monitoring program is a one-time “snapshot” of conditions at a National scale and includes fewer than 10 sites in the DRB.

The DRBC has been collecting streamflow data and monitoring water quality in the DRB since the early 1970’s (Table 1). The Ground Water and Surface Water Use Program is an annual inventory of all consumptive water users of more than 10,000 gallons per day in the DRB. The Scenic Rivers Monitoring Program (SRMP) conducted with the U.S. National Park Service, includes monitoring streamflow and ecological parameters, and analyzing water samples for regulated contaminants and nutrients. In the Delaware River Bio-monitoring Program, benthic macro-invertebrate communities are assessed at 25 sites in the non-tidal Delaware River. The Lower Delaware Monitoring Program (LDMP) includes analyzing water samples for regulated constituents, nutrients, and bacteria at nine sites on the Delaware River and 15 tributaries between the Delaware Water Gap and the head of tide at Trenton, N.J. Fish-tissue samples from five sites on the Delaware River between Trenton and the C&D Canal are analyzed annually for PCBs, chlorinated pesticides, and metals. A special PCB monitoring study includes sample collection at 12 to 15 sites on the mainstem of the Delaware River and in the Bay.

SUMMARY AND CONCLUSIONS

The National Water Quality Monitoring Council (NWQMC) is produced a design for a National Monitoring Network (NMN) for U.S. coastal waters and their tributaries in response to recommendations in the report of the US Commission on Ocean Policy (2004). An objective of the NMN is to link physical, chemical, and biological monitoring in watersheds to estuary and coastal monitoring (http://acwi.gov/monitoring). NMN monitoring would include establishing surface-water monitoring sites at the head of tide at the hydrologic unit code (HUC6) scale to determine the flow and loads of contaminants from watersheds to estuaries. At the HUC6 scale, only one site in the DRB are proposed—the Delaware River at Trenton. Water-quality sampling would be conducted routinely at monthly intervals, and three additional high-flow samples would be collected for a total of 15 samples per year. Data would be collected on a broad spectrum of physical characteristics including streamflow, physical habitat, and suspended sediments, and chemical constituents including nutrients, metals, organic carbon, volatile organic compounds, pesticides, PCBs, PAHs, and new and emerging contaminants. Biological and bottom-sediment sampling would be conducted once per year. This proposed monitoring, subject to approval and funding, will not replace existing monitoring but will enhance other Federal, State, and local programs.

Breakout sessions at the IOOS-NWQMN Workshop at Rutgers University suggested that water-quality monitoring and data storage for the DRB would be enhanced by:

- improved program coordination for monitoring among watersheds above the head of tide, in the estuary, and in coastal areas;
- improved documentation of Quality Assurance Project Plans (QAPPs) including data-quality objectives (DQOs) and method-quality objectives (MQOs) for all monitoring programs to assist in determining data comparability;
- a centralized data exchange for all current and historical monitoring data, including metadata. and a minimum set of water-quality data elements (WQDE);
- more comprehensive physical, chemical, and biological sampling and analyses at all sites using comparable sampling and analytical methods;
- increased monitoring of ground-water and wetlands that may help in determining the transport of contaminants to streams, rivers, estuaries, and coastal zones;
- increased use of real-time monitoring for water-quality conditions and constituent concentrations as new technologies become available.

Coordination of the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA) with the DRBC, USGS, USEPA, NOAA and other Federal, State, and local agencies would help to ensure that monitoring programs in rivers as well as in estuaries, and coastal zones in the DRB are enhanced as per the recommendations from the IOOS-NWQMN Workshop. At the National Water Quality Monitoring Conference in San Jose on May 8-11, 2006, it was suggested that pilot studies be developed to test the NMN design that includes all parts of the hydrologic cycle before full implementation at a National scale (R.M. Hirsch, U.S. Geological Survey, oral commun., May 11, 2006). Members of MACOORA could propose the Delaware River Basin including the Delaware Estuary and the adjacent coastal waters as a potential pilot study area to test the NMN design.

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A SUMMARY OF COASTAL MONITORING PERFORMED BY THE NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION'S (NJDEP), BUREAU OF MARINE WATER MONITORING & STANDARDS

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ABSTRACT

The Bureau of Marine Water Monitoring & Standards (BMWMS) is tasked with all coastal water quality monitoring performed by the New Jersey Department of Environmental Protection, mainly for public health concerns through compliance with the National Shellfish Sanitation Program. Data collected during year-round monitoring for microbial pathogens is supplemented by additional parameters measured in the Coastal Phytoplankton Monitoring Network, Chlorophyll Remote Sensing Cooperative Program, and Toxic Pollutants in Shellfish Program activities. In addition, the New Jersey Coastal Water Quality Monitoring Network (CWQMN) is focused on measuring the ecological health of the State's coastal waters. Complementing this traditional monitoring program is a growing network of real-time water quality sensors placed in New Jersey's coastal waters. The various monitoring programs administered by the Bureau are summarized in this paper, with particular emphasis on Delaware Bay.

INTRODUCTION

Housed within New Jersey Department of Environmental Protection, the Bureau of Marine Water Monitoring & Standards (BMWMS) is responsible for all coastal water quality monitoring performed by the Department. While the largest monitoring effort targets New Jersey's compliance with the National Shellfish Sanitation Program, other ongoing monitoring programs are aimed at measuring the ecological health of the State's coastal waters. The various monitoring programs that the Bureau engages in are summarized below.

National Shellfish Sanitation Program

The national program was established by the Surgeon General in 1925 and is active in all coastal states involved in interstate shellfish harvest and sale. Its purpose is to safeguard against potential consumption of contaminated shellfish by regulating the harvest and sale of shellfish. The data from this program also serve as an important long-term indicator of coastal water quality. The program also requires shellfish producing states to classify their coastal waters according to suitability for safe shellfish harvest. This effort involves the monitoring of pollutant levels in harvest areas, particularly for human pathogens that may be transmitted to consumers by the consumption of tainted shellfish. Each year the BMWMS assesses the most recent water quality and shoreline survey data for compliance with the National Shellfish Sanitation Program guidelines. Waters not in compliance are closed to further harvest.

The Bureau maintains a network of more than 2500 monitoring stations throughout the state's coastal waters including Delaware Bay (Figure 1). These stations are sampled between five and twelve times each year for total coliform and fecal coliform bacteria (indicators of human pathogens). The Bureau's staff at the Leeds Point, NJ facility analyzes the samples.

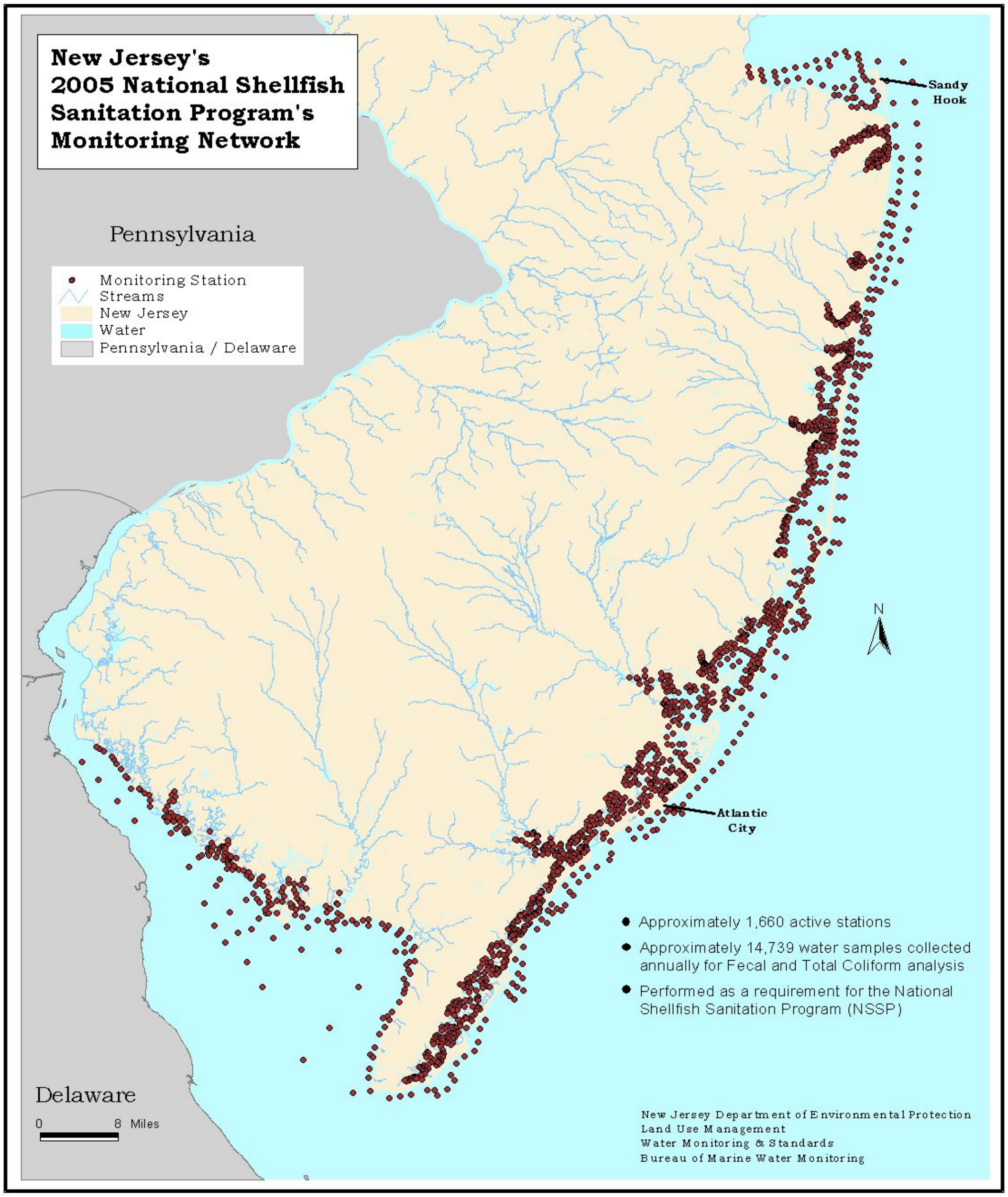

Figure 1. NJ Sampling Locations for the National Shellfish Sanitation Program.

As the leading state in the restoration of coastal shellfish waters (www.nj.gov/dep/bmw), New Jersey has been very successful in improving water quality for shellfish harvesting over the past 15 years (Figures 2 and 3). Currently, 90% of the State's shellfish are harvestable.

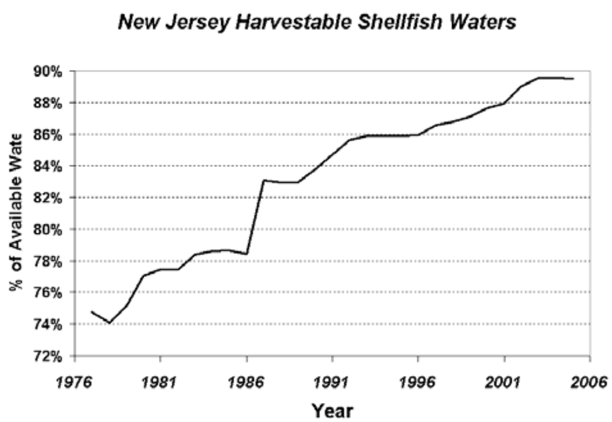

Figure 2. Harvestable shellfish waters in New Jersey, 1977-2005.

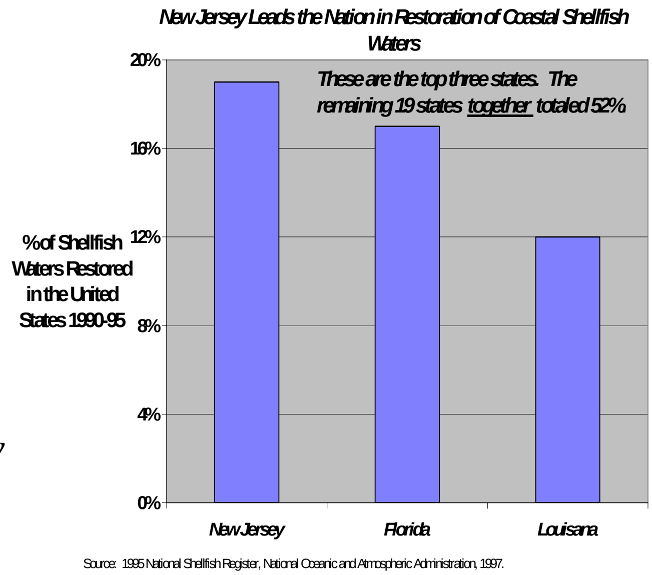

Figure 3. Results of New Jersey's efforts to restore shellfish waters.

Coastal Water Quality Network (CWQN)

The purpose of the CWQN is to provide baseline and trend measures of the ecological health of New Jersey's inshore waters including Delaware Bay (Figure 4). The locations shown in Figure 4 are sampled quarterly each year. Temperature, salinity, total suspended solids (TSS), Secchi depth and oxygen measurements provide information on the environmental stressors that may negatively impact biota and their ecosystems. Nutrients, such as nitrogen and phosphorus, and chlorophyll concentrations correlate with the density of living microscopic plants (phytoplankton) in the water column. Too many or too few phytoplankton can be detrimental to other organisms in the bay and ocean.

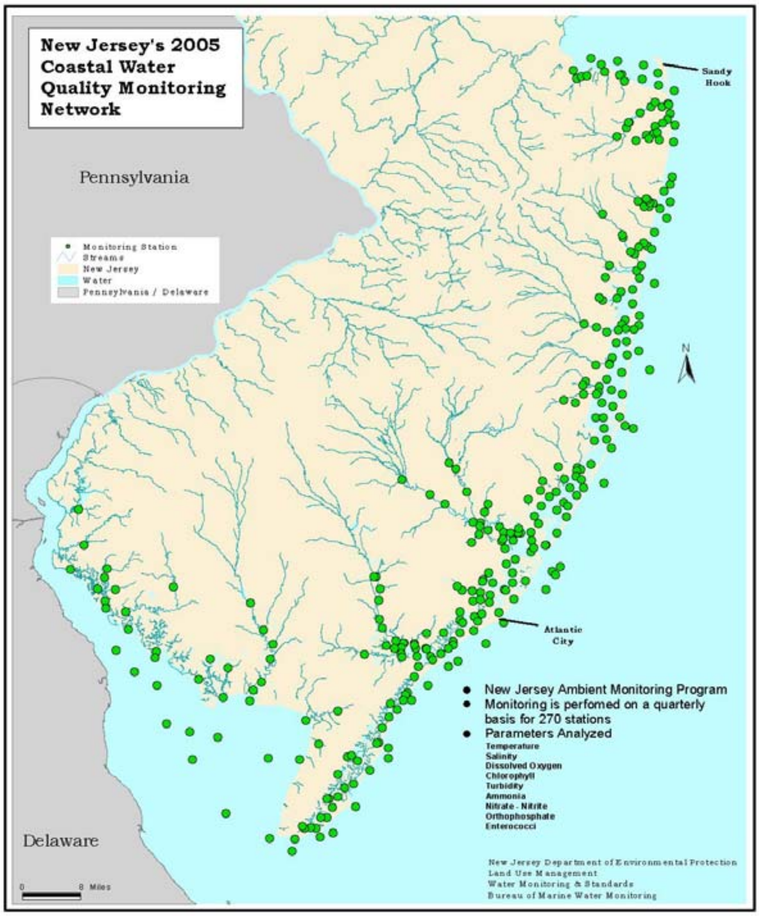

Figure 4. Sampling Locations in New Jersey's Coastal Water Quality Monitoring Network (CWQN).

Cooperative Monitoring Network (Automated Data-Loggers)

The NJDEP began operation of four buoy mounted water quality data-loggers in 2003. The network was expanded in 2005 by the addition of two units by the Barnegat National Estuary Program in cooperation with the Institute of Marine & Coastal Sciences, Rutgers University (Figure 5), and it is anticipated that two more sensors will be added in 2006 through cooperation with Monmouth University. Each automated sensor is programmed to measure dissolved oxygen, salinity, temperature, pH and turbidity every 15 minutes and transmit the data to land-based computers where they are automatically processed in graphic form and then posted on the Bureau’s web page (www.nj.gov/dep/bmw). Data are updated on the web approximately every two hours.

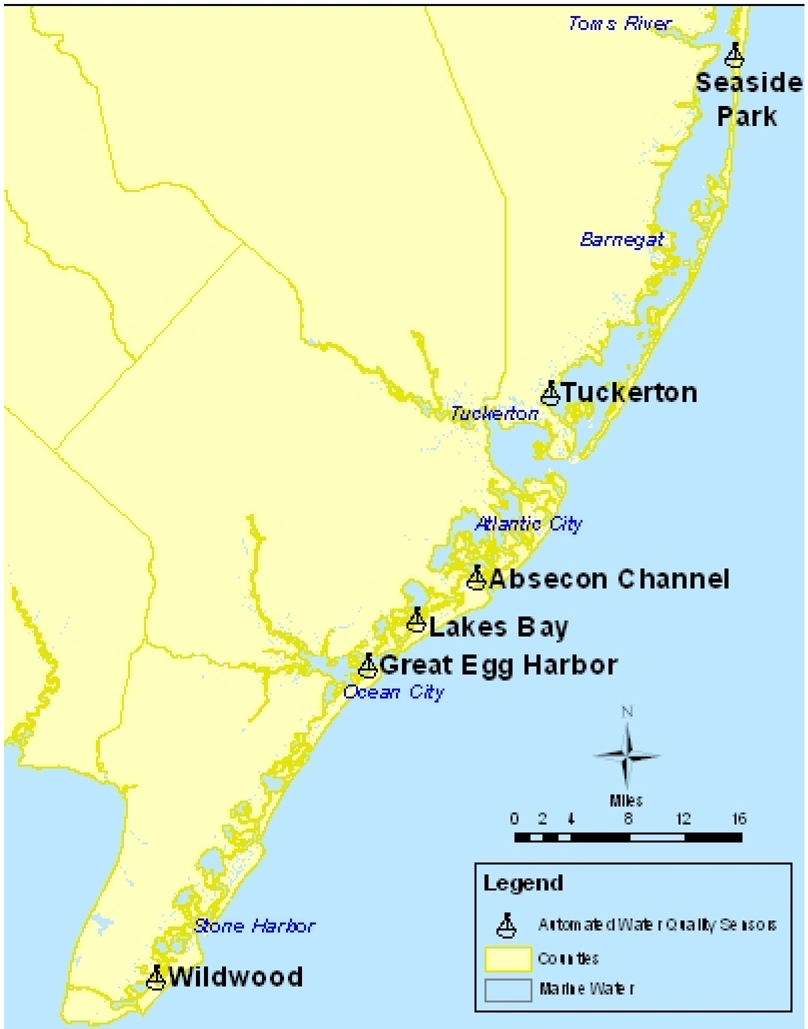

Figure 5. Automated Data-logger Monitoring Locations in New Jersey's Buoy Monitoring Network.

Coastal Phytoplankton Monitoring Network

Each summer, the BMWMS in collaboration with U.S. Environmental Protection Agency (USEPA), Region 2 Office monitors phytoplankton populations in the waters along the 127 miles of New Jersey's coast and major estuaries (Figure 6). Large-scale blooms of these organisms can produce unsightly and unhealthy water quality conditions, often referred to as red, green or brown tides, depending on the dominant taxa. When phytoplankton die, the decay of their biomass may create substantial oxygen demand in the water column, sometimes reducing bottom oxygen concentrations below tolerable levels to larger organisms, such as fish and shellfish. Some of the species that create red tides are also known to have potentially harmful effects on human health, either through direct contact or through ingestion of shellfish that have become contaminated with these microorganisms. Fortunately, to date, New Jersey's red tides have not been of the acute toxic variety. The results of the sampling effort also provide estimates of other phytoplankton present that might have negative effects on marine fauna and result in mild toxicity to bathers.

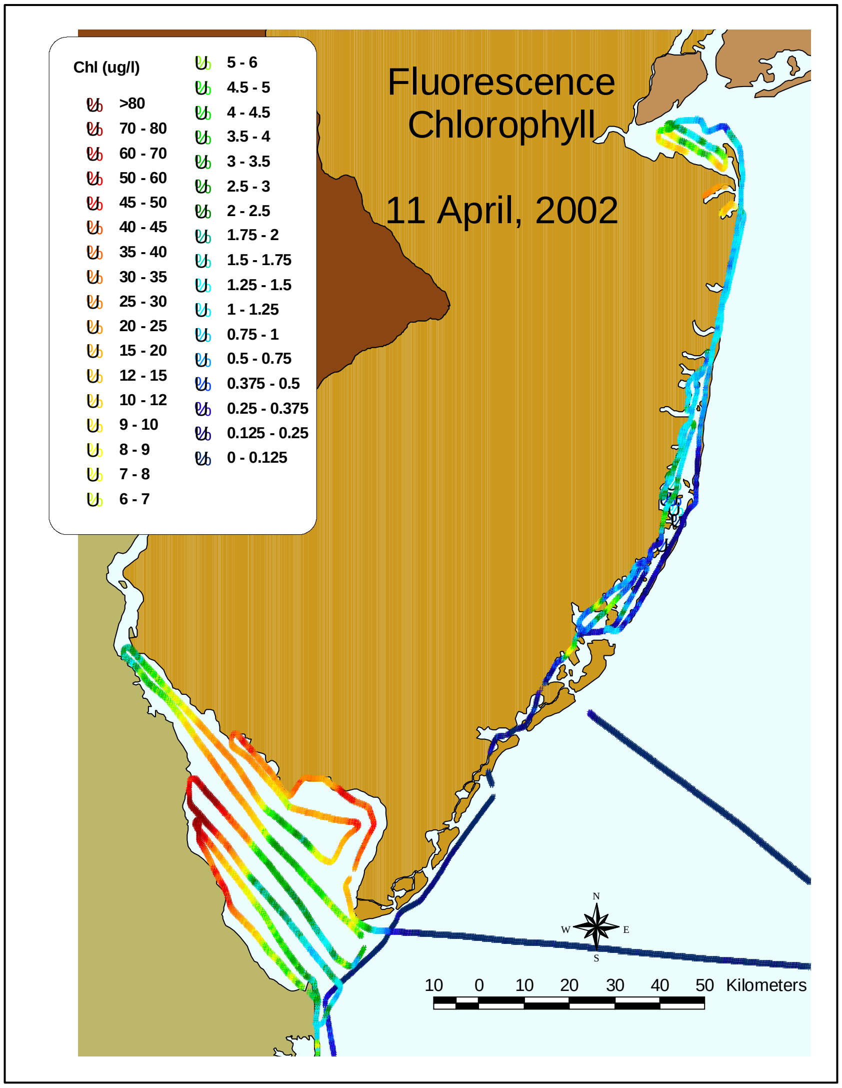

Figure 6. Airborne remote sensing for chlorophyll concentrations.

Under the guidelines of the National Shellfish Sanitation Program, the Bureau maintains a network of stations as part of New Jersey's contingency plan to monitor for marine biotoxins. Stations are sampled biweekly from May through August each year by the USEPA through a cooperative agreement with the NJDEP. The Bureau analyzes the samples for the presence of potentially toxic forms of phytoplankton.

Chlorophyll concentrations are measured along transects by remote sensing from a passing aircraft (Figure 6). During each fly-over, information is collected as a collaborative effort between the BMWM, the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA). High chlorophyll concentrations may indicate the presence of a phytoplankton bloom. Remote sensing compliments more traditional fixed-station monitoring performed by the Bureau (Figure 7) (www.state.nj.us/dep/wmm/bmw).

No blooms of toxin producing algae have been detected in Delaware Bay since the inception of the program. However, non-toxic "brown tides" have been recorded in Barnegat Bay. Similarly, a non-toxic dinoflagellate bloom occurred off the coast of Ocean City, NJ in 2002. Neither of these blooms resulted in the significant water quality impairments to fisheries and tourism that occurred with blooms in New Jersey waters during the mid-1970's and mid-1980's.

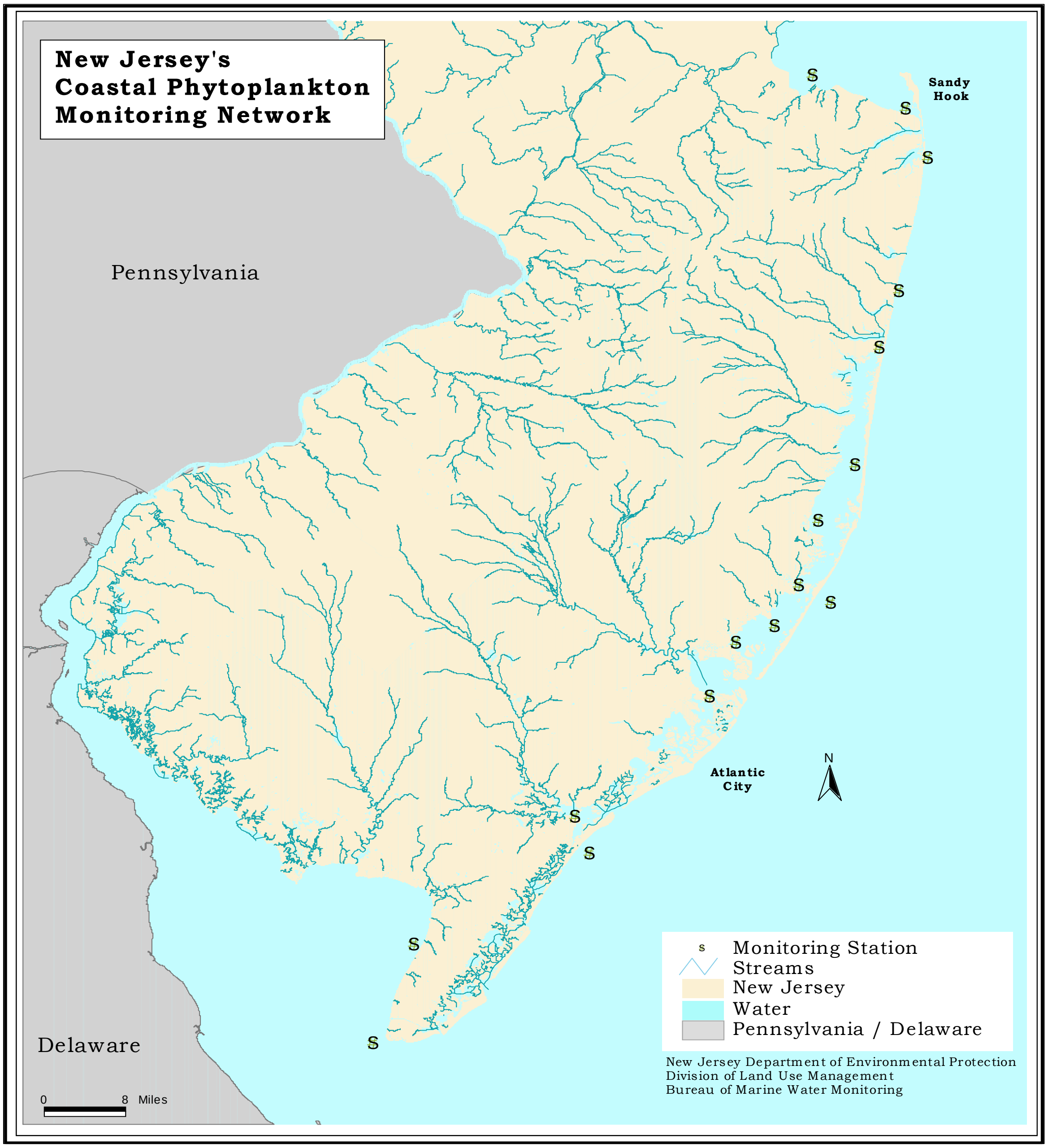

Figure 7. Sampling locations for New Jersey's Coastal Phytoplankton Monitoring Network.

Toxic Pollutants in Shellfish

Shellfish are an important to the economy of southern New Jersey. Because they filter large quantities of water and accumulate pollutants to levels many times higher than in the ambient water column, they are also excellent indicators of toxic pollutant levels in coastal waters. For this reason, monitoring for potential contaminants in shellfish tissue for metals (arsenic, cadmium, chromium, mercury, lead and nickel) and total polynuclear aromatic hydrocarbons (PAH's) in shellfish was initiated in 2004-2005 at 84 estuarine locations in southern New Jersey (Figure 8). By comparing monitoring results to established federal standards and guidelines for safe consumption of shellfish (http://www.nj.gov/dep/bmw), the program helps give the public including commercial and recreational fishermen a better understanding of the water quality in the region.

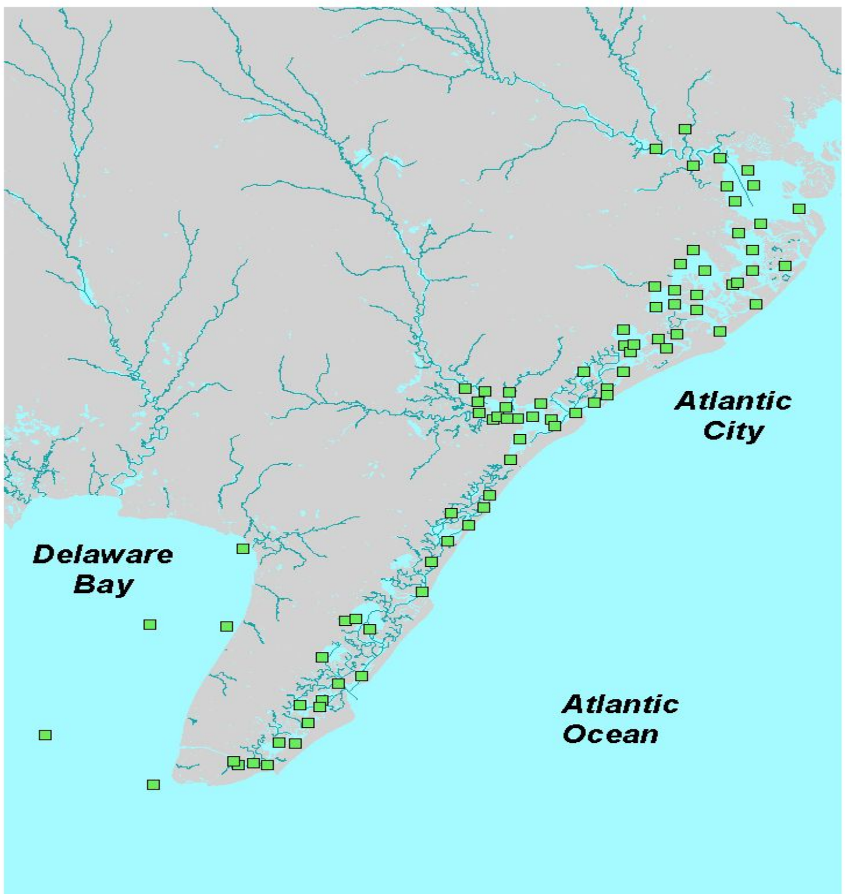

Figure 8. Sampling Locations for New Jersey's shellfish toxics monitoring program.

A NATIONAL WATER QUALITY–OCEAN OBSERVING SYSTEM IN DELAWARE ESTUARY:

SEDIMENT MANAGEMENT AND RESEARCH APPLICATIONS

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ABSTRACT

Fine-grained sediment (mud) is central to a number of chronic problems in the tidal Delaware River, estuary and bay including shoaling of shipping channels, dispersal of particle-associated contaminants, and reduced primary production. To assist environmental managers, engineers and researchers in addressing these problems, system-wide timeseries measurements of water properties are needed to facilitate trend analysis and predictive modeling. The proposed ocean observing system for Delaware Estuary has potential to meet this need, and on the long term provide datasets required to identify temporal patterns related to climate change, sea-level rise and human disturbance. Delaware Estuary has a long history of human intervention through various engineering practices, the latent effects of which we are just beginning to understand.

INTRODUCTION

This document presents rationale for a program of continuous, regional observations of water properties in support of sediment management and research needs in Delaware Estuary, just one promising application of the proposed National Water Quality Monitoring Network-Integrated Ocean Observing System (IOOS). Presently, there are two University of Delaware observing systems in place: 1) Delaware Environmental Observatory (DEOS; www.deos.udel.edu); and 2) Delaware Bay Observing System (DBOS; www.udel.edu/dbos). These systems along with NOAA and USGS sensor installations provide hydrologic, meteorological and hydrodynamic information broadly relevant to sediment transport in the estuary, but not the types of data needed to quantify sediment flux. As detailed herein, continuous timeseries of sediment flux are vital for predicting shoreline and bathymetric change related to natural and anthropogenic factors.

The Sedimentary System

The Delaware Estuary supports one of the world's largest freshwater ports, the Philadelphia–Wilmington complex, second only to New York Harbor in terms U.S. inland ship traffic. The estuary also sustains the longest continuous salt marsh systems on the U.S. Mid-Atlantic coast, though there is mounting evidence of rapid degradation over the past several decades (e.g., Kearny et al., 2002). Many of the perceived problems related to sediments in the estuary, channel shoaling for example, are in fact innate and linked to regional patterns of tidal and density-driven circulation. Accordingly, a broad perspective is required to understand the nature of localized sedimentation conditions. The highly industrialized port complex happens to fall within the estuarine turbidity maximum, a quasi-stationary zone of elevated suspended-sediment concentration maintained by converging residual flows in conjunction with tidal settling–resuspension cycles. Turbidity maxima are innate features in virtually all river-estuaries, and moderate the throughput of suspended matter from upland source areas to downstream estuarine environments. Turbidity maxima processes are intrinsic to the morphologic equilibrium of estuarine channels and contiguous tidal wetland coasts, although sediments trapped within these zones quite often interfere with human activities.

The general circulation of Delaware Estuary is fairly well-known, but by comparison the sedimentary system is poorly understood. Indeed, we are just beginning to understand the underlying processes and rates of sediment movement from results of bottom geophysical surveys, timeseries observations of sediment transport, and sediment budgeting (Sommerfield and Madsen, 2004; Walsh, 2004; Cook et al., in review). A complicating factor is routine maintenance dredging by the U.S. Army Corps of Engineers (USACE), which on average removes more sediment from the estuary annually than is supplied by river tributaries. On the long term, systematic removal of sediment has potential to starve the estuary, perhaps resulting in erosion of the seafloor and shoreline, and there is some evidence that this is now taking place (Walsh, 2004). Sediment budgets are one approach to studying how sediment loads are partitioned in estuaries, and when aided by numerical models (e.g., HydroQual's ECOMSED) can be performed at acceptable levels of confidence. However, model testing and calibration demand high-quality hydrodynamic and sediment-concentration datasets, and here lies a potential function of the proposed Delaware Estuary IOOS. An immediate objective of this observing system should be to provide information needed to model and predict material fluxes and pathways associated with extreme events such as floods and storms and unfortunate accidents such as spills of oil and hazardous substances. At the same time the IOOS should be designed to address longer-term concerns, for example, changes in estuarine water properties and morphology related to climate variability, sea-level rise and human activities.

Existing Data Gaps

Lack of long-term hydrodynamics and sediment transport observations for Delaware Estuary waters presents major challenges to those involved in water-quality modeling, benthic habitat assessments and waterway engineering. At present, only a handful of U.S. Geological Survey (USGS) turbidity sensors are maintained in the estuary monitor changes in sediment concentration. Apart from USGS stations and periodic boat runs conducted by the Delaware River Basin Commission (DRBC), no state or federal agency has implemented an integrated program of regional sediment management. Although work by University of Delaware researchers has helped address specific gaps in knowledge, available datasets are insufficient for predicting long-term trends in the sedimentary system. By providing high-density, uninterrupted datasets the proposed IOOS thus has potential to fill this void. Among other reasons, a regional sediment management program based on real-time, in-situ observations could help assess the immediate and latent effects of engineering works in the estuary, in particular, channel deepening and maintenance dredging. As detailed below, dredging has modified the estuary's innate hydrodynamics and sedimentation patterns, and work is needed to understand the broader implications of these changes.

Consequences of Dredging

Beginning in the late 1800's the depth of Delaware Estuary has been deepened incrementally to accommodate ships of ever-increasing draft—the axial shipping channel is now two times deeper than the depth of the natural thalweg. Since completion of the 215-km long shipping channel in 1960, nearly annual maintenance dredging has been required in some segments to maintain the specified depth of 40' (12.2 m). Significantly, by increasing the channel cross-sectional area (and reducing bottom friction) channel deepening increased the estuary's tidal range at the head-of-tides, and decreased the mouth-to-head propagation speed of the tide by several hours (DiLorenzo et al., 1993). To detail morphologic changes directly and indirectly related to the deepening, we performed a morphometric analysis of the subtidal estuary using synoptic bathymetric soundings available for the period 1878–1987 (Walsh, 2004). Bathymetric data from agency hydrographic surveys in 1878–88, 1945–60 and 1985–87 were compiled, datum-normalized and gridded at 5-m resolution to create a series of digital depth models of the seafloor. Temporal changes in estuarine hydraulic geometry (depth, width and cross-sectional area) and volume were computed by differencing successive bathymetric surfaces, and residual volume was converted to sediment mass using bulk-density data for Delaware Estuary strata. For the 117-km segment between Philadelphia and the bay head, the bathymetric residuals were used to identify spatial patterns of sediment accretion and erosion, and also and to develop a sediment budget representative for the past several decades.

From 1878–88 to 1945–60 (Period 1), the sectionally averaged (mean) depth and width of the estuary increased and decreased by 1.35 m and 148 m, respectively, altogether increasing mean cross-sectional area by ~1,200 m^2. Morphologic change during this period was largely a consequence of the deepened channel along with shoreline development and bulkheading to a lesser extent. From 1945–60 to 1980–87 (Period 2) mean depth increased by 0.25 m and mean width increased by 216 m, together increasing the cross-sectional by 1,764 m^2. Period 2 changes reflect mostly natural accretion and erosion following disturbances brought about by channel construction during Period 1. From 1878 to 1987 the overall subtidal volume of the estuary increased by 3.3 $x10^8$ m^3 (17 % increase), but the rate of change was two times greater during Period 1 than Period 2.

As illustrated in Figure 1, spatial patterns of bathymetric change reveal that accretion occurred almost exclusively on the subtidal shoals and flats (<6 m water depths), whereas erosion was predominant throughout the deeper estuary adjacent to the shipping channel. The actual mechanism of erosion is unknown, though intensified tidal stress related to the deepened channel and (or) scour induced by the pressure wave of passing ships are probable explanations. Regardless, seafloor erosion within the non-dredged areas removed an estimated $1.4x10^{11}$ kg of sediment during Period 2 for a mean erosion rate of $3.4x10^9$ kg/yr. This previously unknown sediment source is quantitatively important as it exceeds the mean annual influx from rivers ($1.3x10^9$ kg/yr), and up-estuary redistribution of eroded sediment may contribute to rapid

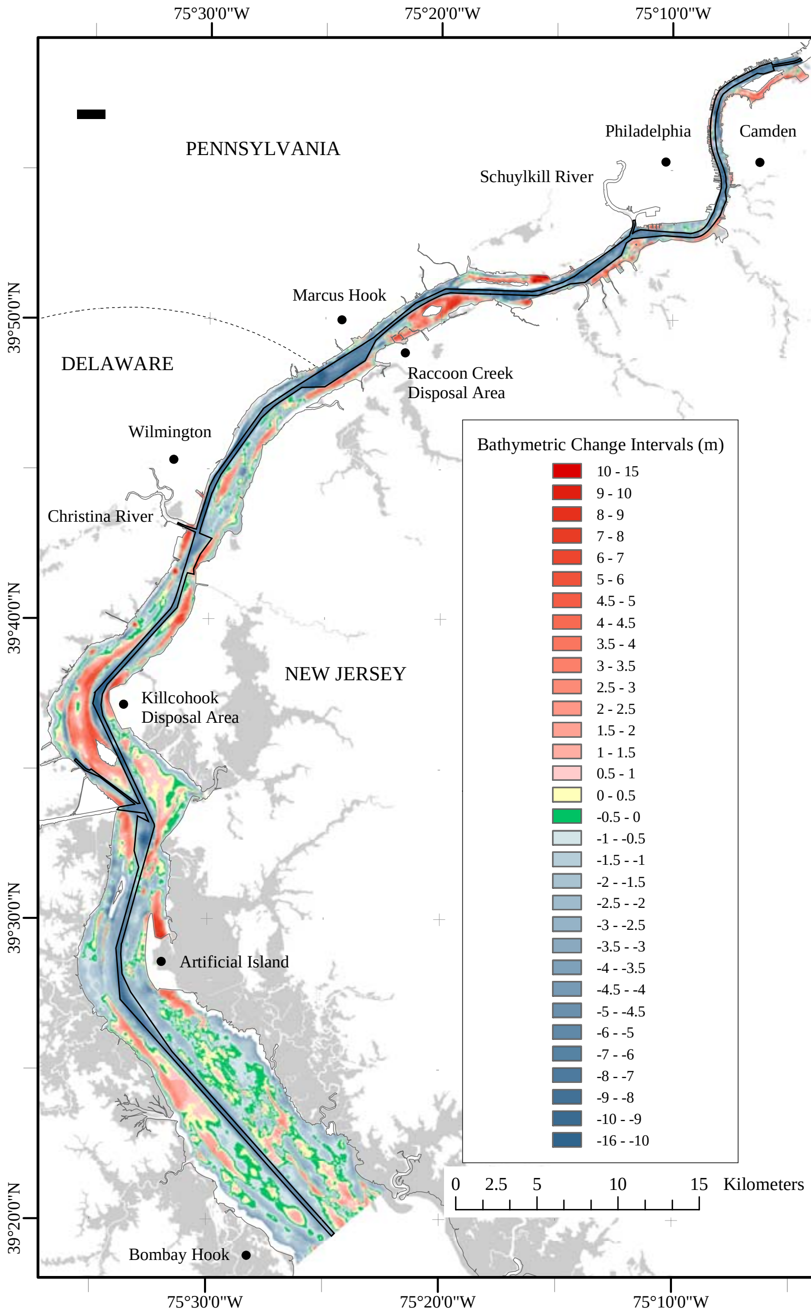

Figure 1. Morphologic change in Delaware Estuary from 1877 to 1987 based on analysis of datum-normalized bathymetric data (Walsh, 2004). *The axial shipping channel is bound by the black lines. Channel deepening (dredging) to a uniform depth of 12.2 m during 1945–1960 is chiefly responsible for the increase in axial depth. Erosion adjacent to the channel is in some manner related to the deepened channel.*

infilling of the shipping channel in landward reaches. In sum, between 1877 and 1987 there was a net loss of fine-grained sediment in Delaware Estuary due to the collective effects of channel deepening, natural (but human influenced) seafloor erosion, and maintenance dredging. Nearly annual maintenance dredging continues to present, and there are plans pending to further deepen the full extent of the channel to 45' (13.7 m). Needless to say, the continued removal of fine-grained sediment has major implications to the equilibrium morphology of the estuary including its tidal wetland coasts. Additional research, perhaps aided by the proposed IOOS, is needed to elucidate short-term and latent impacts of these and other human activities in Delaware Estuary.

Conclusion

The proposed Delaware Estuary IOOS has potential to address a number of engineering and environmental issues associated with sedimentation by providing continuous, regional-scale observations of currents and suspended-sediment concentration. Among other applications, an IOOS optimized for sediment studies could potentially be used to quantify fluxes of sediment mass among flow-linked environments in support of a regional sediment budget. Long-term datasets provided by the IOOS could also be used to predict impacts of sea-level rise and engineering works on basin morphology and ecosystem health. While promising, the proposed IOOS will require considerable financial and intellectual commitments by federal and state agencies in cooperation with regional scientists, engineers and environmental managers.

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ECOSYSTEM RESPONSE WITH WATER QUALITY MONITORING ON THE DELAWARE ESTUARY

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ABSTRACT

Scientists at the University of Delaware, College of Marine and Earth Studies have conducted long-term water quality monitoring of the Delaware River and Bay beginning in 1978. Since the mid-1980s, data were collected at a series of regular stations from the head of tide to the Bay mouth, most co-located with Delaware River Basin Commission (DRBC) sites. Although long-term trends in dissolved oxygen and other water quality parameters have shown some improvement, discrete sampling is recommended along the full length of the estuary. Monitoring should also be expanded to include estimates of watershed inputs to the main stem of the Delaware Estuary and to some of its sub-estuaries. Decreases in oxygen in the tidal river could re-occur in the future from excess algal production if production were to increase. There is also some concern about minor hypoxia in the shallow edges of the lower Bay and even bottom water hypoxia if the hydrological cycle were altered by climate change. For all these reasons, there should be better routine oxygen monitoring. In addition, estuary-wide synoptic oxygen measurements can give an estimate of net autotrophic-heterotrophic balance, which is important for a more ecosystem-based understanding of the ecosystem.

INTRODUCTION

My research group at the University of Delaware (UD), College of Marine and Earth Studies has been studying the Delaware Bay Estuary since 1978 through a variety of research programs whose results have been disseminated to other scientists, decision-makers and the general public. Most projects have included auxiliary sampling of routine water quality along the full salinity gradient (often also including tidal fresh portions) of the Delaware River: temperature, salinity, dissolved oxygen (DO), dissolved inorganic carbon (DIC), dissolved organic carbon and nitrogen (DOC and DON), seston, particulate carbon/nitrogen ratios, chlorophyll, nutrients, light attenuation, and depth-integrated primary production. Sampling has been performed during 1-13 annual cruises aboard the *RV Cape Henlopen* each lasting 1-4 days on more than 100 occasions over 27-years. Since the mid-1980s, data were collected at up to 26 sampling stations from head of tide to the Bay mouth; many of the stations are at the same location as those monitored by the DRBC. Recently, DRBC has expanded its sampling to the Bay mouth as well, using our lower Bay stations. Other investigators at the College of Marine and Earth Studies also have used our stations for microbial and geochemical studies.

Our entire dataset, along with metadata are available in Excel format for the period 1978-2003 (http://www.ocean.udel.edu/cms/jsharp/CruiseDatabase.htm). The data and concomitant analyses have been used by the DRBC in the development of water quality and PCB models to address resource management issues.

Oxygen Depletion in the Delaware Estuary

The upper drainage basin of the Delaware Estuary was in the past, and still is a relatively clean source of drinking water and serves as a wild and scenic recreation area (Figure 1).

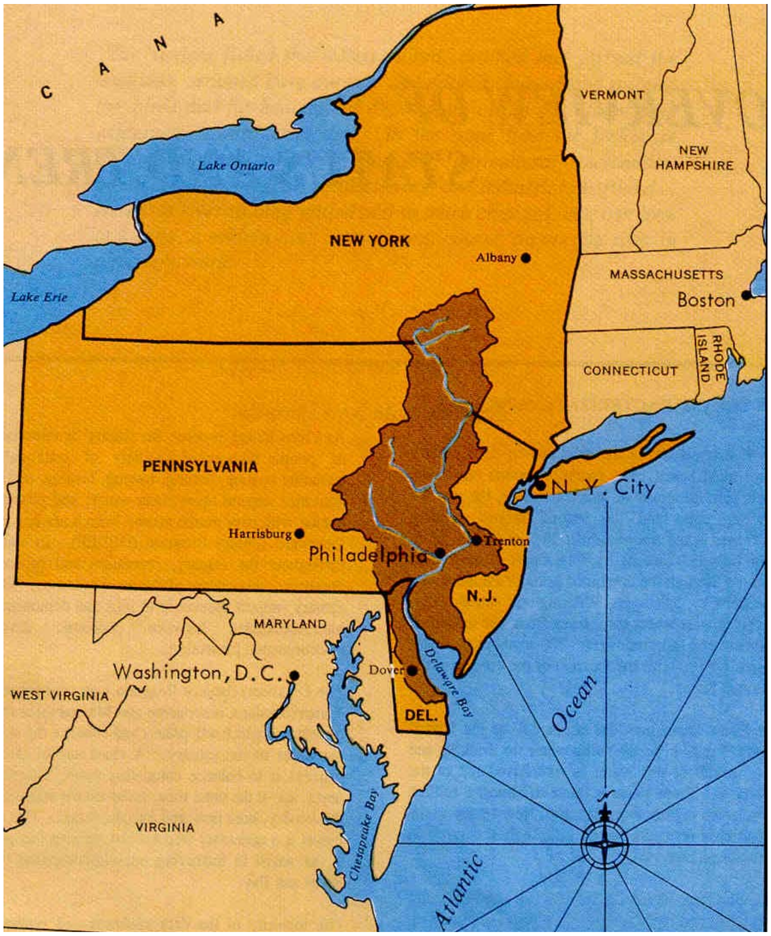


Figure 1. The Delaware River and Bay with drainage basin. *The drainage basin is in the states of New York, New Jersey, Pennsylvania, and Delaware. The head of the tide of the Delaware River is near Trenton, NJ. From there through the Philadelphia area, the tidal river is freshwater. The salinity gradient begins around the PA-DE border and goes to the mouth of the Delaware Bay where the salinity is about 30. The upper drainage basin supplies a very clean drinking water supply to the New York City area. Parts of this upper drainage basin were one of the first areas in the US to be designated with the "wild and scenic river"status in the 1970s. The lower tidal river, the urban region, has massive municipal and industrial inputs. At one time this urban river region was considered one of the most polluted in the US. The lower saline estuary can be viewed as a relatively "healthy" ecosystem, partially due to a buffering effect of the extensive marsh periphery.*

The urban river region near Philadelphia has suffered from a long history of periodic low oxygen events due to wastewater effluent derived Biochemical Oxygen Demand (BOD) as well as experiencing high contaminant inputs. Because the water column of the lower estuary is well-mixed during the warmer months of the year, it does not have isolated bottom waters that can lead to periodic hypoxia and/or anoxia events. There is much concern about bottom water oxygen depletion in other estuaries, most notably the Chesapeake Bay. This feature of non-stratification in the summer is the main reason that the Delaware does not suffer from symptoms characteristically associated with eutrophication.

The five regions that we have used to discriminate the chemical and biological processes of the Delaware Estuary are shown in Figure 2.

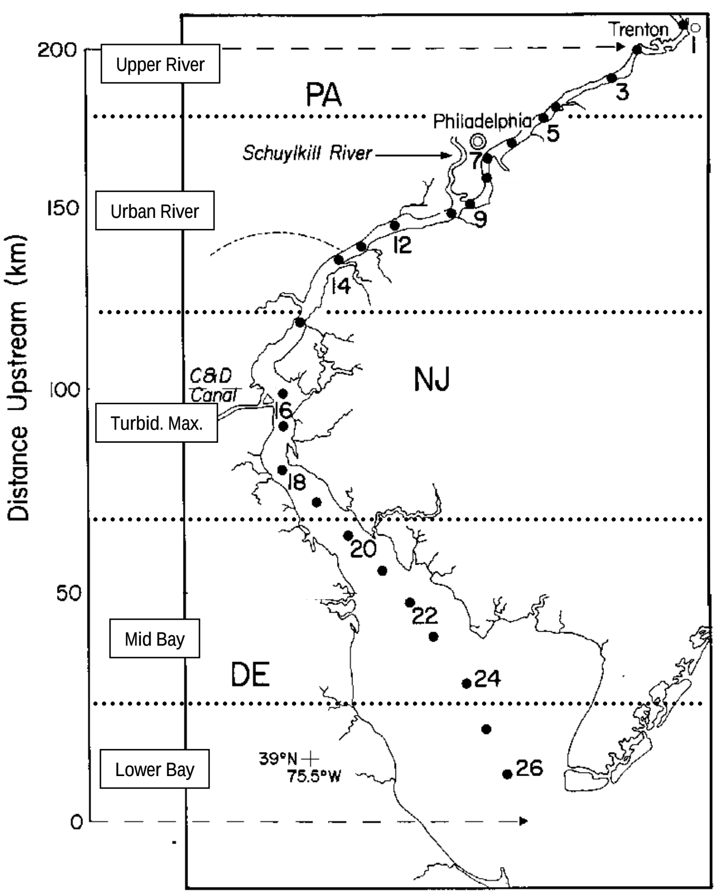


Figure 2. The Delaware Estuary with distances from mouth of Delaware Bay (0) in km. *Regularly sampled stations from 1 (210 km, near head of tide) to 26 (at mouth of bay). We have separated the estuary into 5 regions; they are (with characterizations): upper tidal river (clear water, composite agricultural and municipal inputs from above the fall line). Urban river (relatively clear, local massive municipal and industrial inputs). Turbidity maximum (very high total suspended sediments, TSS, from tidal resuspension of bottom sediments, strong light limitation). Mid-bay (grading from turbid to clear, relatively high nutrients grading to low). Lower bay (clear water, grading to nutrient limitation).*

The simulated trend line for dissolved oxygen concentrations in the Philadelphia area (Figure 3) is based on the realistic proposition that the waters should have been close to saturation in 1880 and is calculated on the basis of extensive monitoring data for the period of 1967 to the present, and less frequent monitoring numbers for the 1940s-60s.

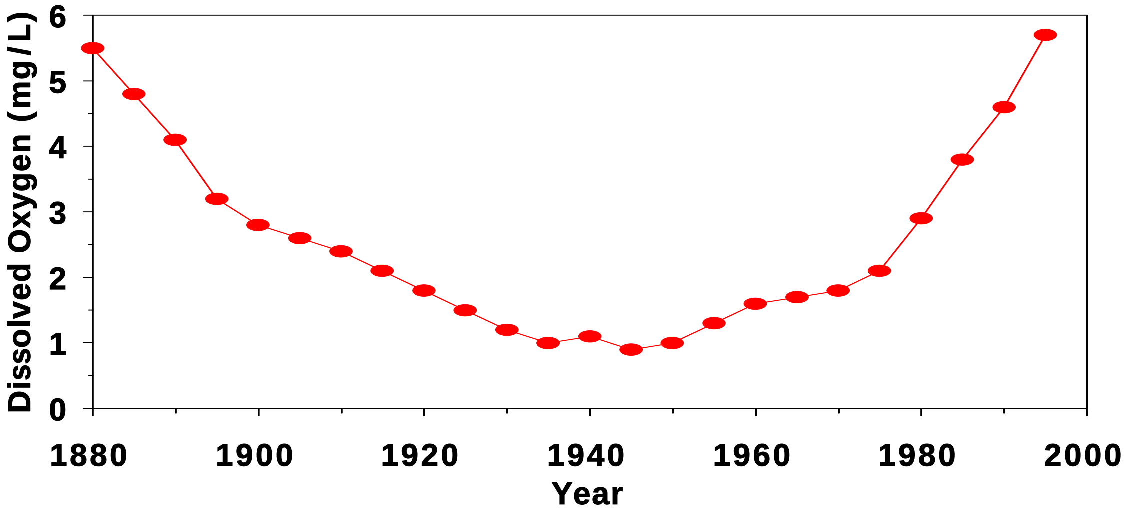


Figure 3. Simulated record of dissolved oxygen for the Delaware River at Philadelphia. *Detailed data used for 1967-1999 curve. Limited data used for shape of the curve from 1940s-1967 Assumed oxygen saturation concentration for 1880 from anecdotal information about fisheries.*

The improved water quality observed today is due directly to improved sewage treatment in the region and reduction of BOD. Similarly, the input of dissolved inorganic nitrogen (DIN = nitrate and ammonium) near Philadelphia from 1913 to the 1990s (Figure 4) is typical of the large increases in DIN seen in estuarine and coastal waters around the world. Also note that the large increase in ammonium is followed by a decline in the early 1970s associated with improved wastewater treatment.

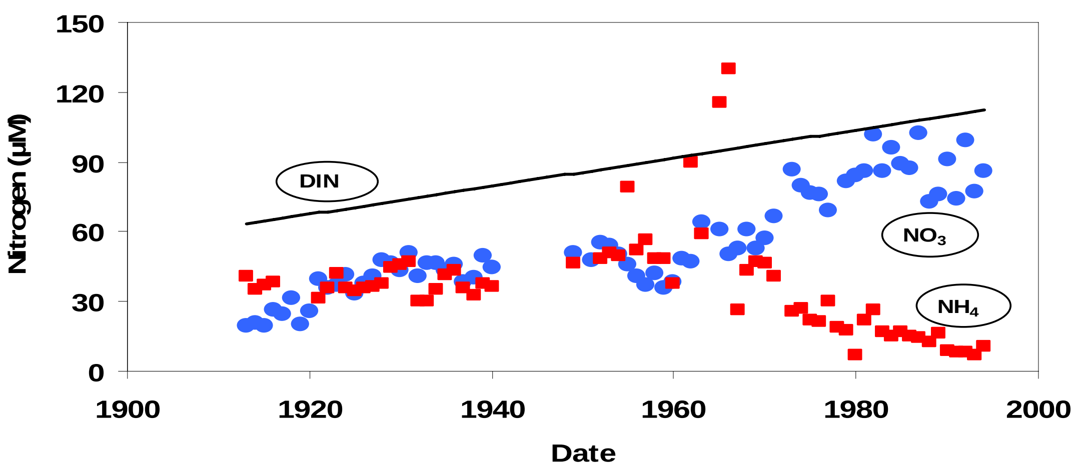


Figure 4. Nitrate and ammonium nitrogen concentrations in Delaware River in Philadelphia area from 1913 – mid 1990s. *Data from the Philadelphia Water Department collected by N. Jaworski.*

Summer time dissolved oxygen concentrations along estuarine axis exhibited sags between the urban river region and turbidity maximum zone in 1972 (Figure 5).

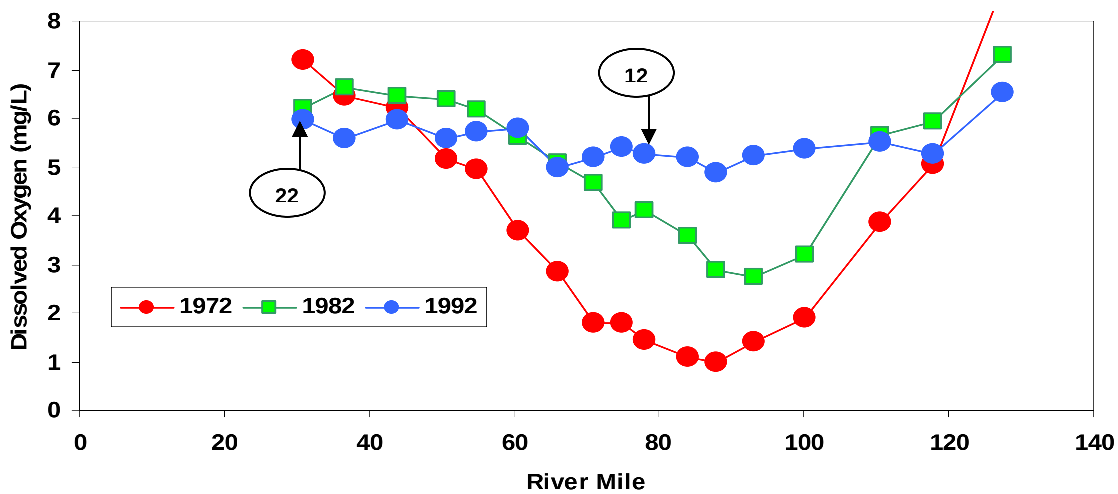


Figure 5. Dissolved oxygen concentrations along the length of the Delaware Estuary. *Summer averages for 1972, 1982, and 1992. Location of station 12 in the river and station 22 in the bay shown. Data from Delaware River Basin Commission (DRBC) routine monitoring.*

By 1982, this pattern diminished and was essentially eliminated by 1992. A time trend near Station 12 in the urban portion of the river (about 130 km) shows the large improvement in water quality due to decreased oxygen demand (Figure 6).

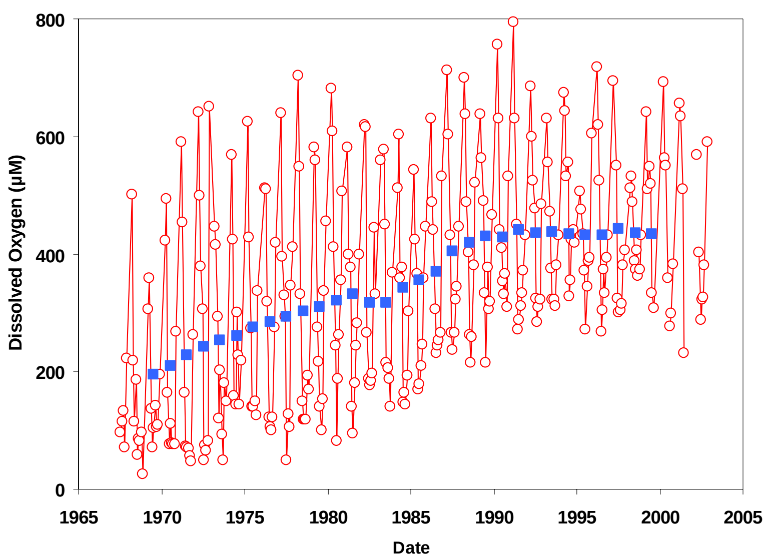


Figure 6. Dissolved oxygen concentration in the Delaware River surface waters near our station 12. *Data from DRBC routine sampling. Open red circles represent monthly average values; solid blue squares are 5-year running average values.*

In Figure 7, modern summer oxygen data are shown as four individual transects measured over the past 6 years; in this case, oxygen is shown as percent saturation.

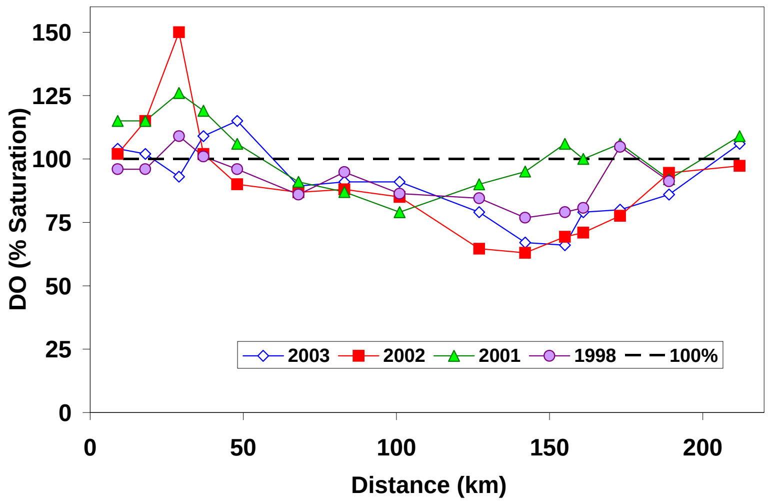


Figure 7. Summer dissolved oxygen saturation along the length of Delaware Estuary from individual sampling runs. *Differences in oxygen undersaturation in the urban river region (120-170 km) are due to day-to-day meteorological differences; note, varying levels of supersaturation in the lower bay (20-50 km range)*

While the extreme oxygen sag of the past is not seen, noticeable oxygen undersaturation is observed periodically. Positive deviations from saturation of similar magnitude are seen in the lower estuary. These excursions are essentially daily phenomena enhanced by meteorological control as opposed to the semi-permanent summer undersaturation of the past. A three decade analysis similar to that shown in Figure 6, but in this case for station 22 (around 50 km) in the lower estuary, does not exhibit the large oxygen depletion events seen in the urban river and turbidity maximum regions (Figure 8).

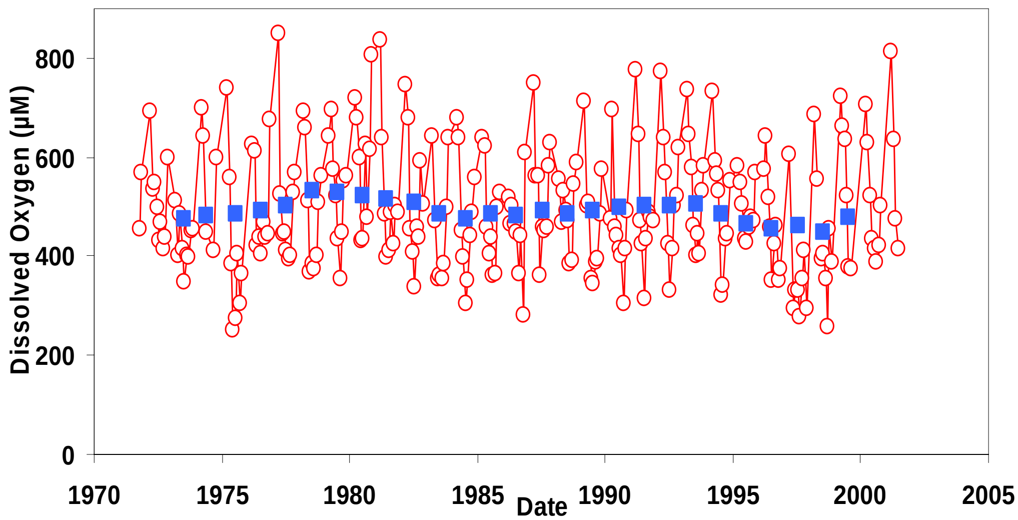


Figure 8. Dissolved oxygen in surface waters at station 22 in the Delaware Bay. Data from DRBC routine sampling. *Open red circles represent monthly average values; solid blue squares are 5-year running average values. Note that unlike the urban river, there is no noticeable trend in this bay region over the 30-year period.*

Similarly, the trend for ammonium nitrogen at the urban river Station 12 is complementary to the oxygen picture shown in Figure 6 (Figure 9). A very large drop is seen in ammonium and is partially accompanied by an increase in nitrate; overall, there is a slight decline in total dissolved inorganic nitrogen. Probably, the ammonium itself was a major oxygen sink in the past (nitrification oxidizing it to nitrate).

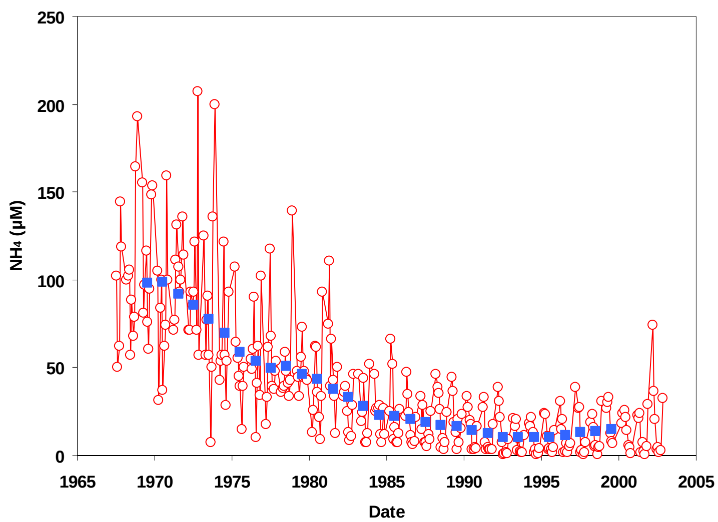


Figure 9. Ammonium nitrogen at station 12 in the urban river. *Data from DRBC routine sampling. Open red circles represent monthly average values; solid blue squares are 5-year running average values. Note the large drop in ammonium concentration, most dramatic in the period between 1970 and the early 1980s.*

Much of the decrease in oxygen demand has been attributed to a decrease in carbonaceous BOD inputs; a significant drop in the dissolved organic carbon in the water between the late 1970s and late 1980s is consistent with this attribution (Figure 10).

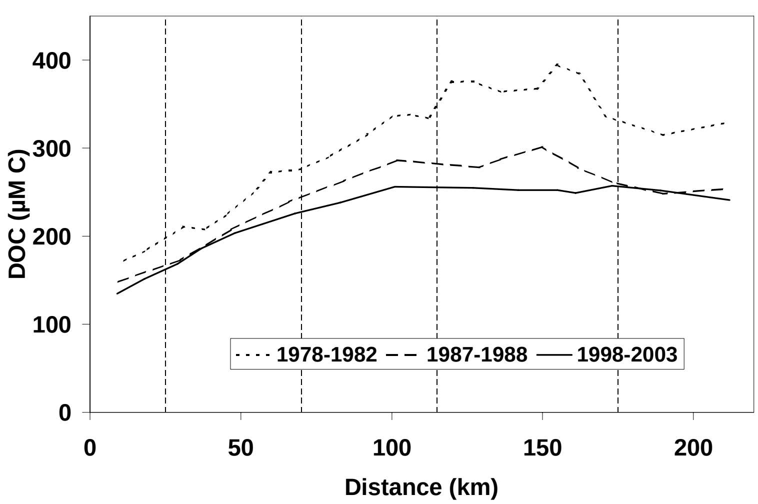


Figure 10. Dissolved organic carbon (DOC) down the length of the Delaware Estuary for three periods over several decades. *Data are from our sampling. A decrease in the amount of DOC is seen down the full length of the estuary, especially as the difference between the late 1970s and 1980s. The largest DOC drop is seen in the urban river region.*

Linkage to Biological Activity

There is considerable concern today about hypoxia (oxygen depletion) due to nutrients stimulating excess algal production and the excess organic matter causing an oxygen demand. Usually, the modern concern is about oxygen depletion in bottom waters which occurs because of summer stratification. Today, the oxygen demand has decreased sufficiently for air exchange to overcome microbial metabolism. In the past, this was not the case and even the well-mixed waters showed hypoxia from top to bottom. The most nutrient-rich urban river region has lower primary production than the lower bay and does not show accumulation of large amounts of biomass, nor does it show high DOC. The high oxygen demand of the past appears to have been due to allochthonous reduced materials (organic matter and ammonium) entering from effluents and not due to autochthonous production. In the spring, the lower Delaware Estuary does experience extended stratification due to high flow; but at this time of year, microbial metabolism is low due to cold waters. Through the warmer months of the year, normal flow is low and the waters mix throughout the water column. If higher flows were to occur in the summer, stratification could occur. Several recent storm-driven high flow events suggest that with climate change, summer stratification could set up and bottom water oxygen depletion could occur.

The past several decades have witnessed large changes in nutrient concentrations and forms, especially in the urban river region. The high oxygen-demanding ammonium concentration has declined. In addition, total P has dropped about 80%, most abruptly in the early 1970s. The N/P ratio of nutrients is very different today throughout the estuary. However, overall nutrient concentrations are very high and there are large seasonal and spatial shifts. We do not have extensive information about the overall ecosystem nature of the estuary and even though the high nutrient concentrations do not give rise to typical symptoms of eutrophication in the estuary, more subtle influences on the ecosystem are unknown. In addition, there is concern that the Delaware Estuary is a major exporter of nitrogen and phosphorus to the coastal ocean.

FUTURE MONITORING NEEDS

Routine monitoring from the DRBC has provided a good time-series of parameter trends. Because we need discrete sampling along the full length of the estuary, this monitoring should continue. We also need better estimates of watershed inputs to the main stem of the Delaware Estuary and to some of the sub-tributaries. The large inputs from the urban river region appear to be much larger than nutrient inputs from the watershed under normal conditions and high suspended sediments in the turbidity maximum region of the estuary are largely due to resuspension of bottom sediments. However, sporadic storm inputs can create the situation of watershed inputs overwhelming the system in terms of suspended sediments and organic matter. In addition, these storm events could set up stratification in the lower estuary in the summer; a situation that does not normally occur today with the normal low flow condition. The USGS gauging stations at the heads of the tide in the Delaware and Schuylkill rivers should be maintained well and records coordinated better with the DRBC discrete sampling.

There are several continuous monitoring stations in the tidal river region that are maintained by the USGS. These should continue and should be complemented by more continuous oxygen monitoring stations in the bay; it is especially important to have surface and bottom continual monitoring in the lower bay. Decreases in oxygen in the tidal river could occur in the future from excess algal production if production were to increase. There is some concern about minor hypoxia in the shallow edges of the lower bay; these should be better monitored. Also with changed rainfall patterns due to climate change, summer high flow could cause stratification and bottom water hypoxia could become a periodic event. In addition, estuary-wide synoptic oxygen measurements can give an estimate of net autotrophic/heterotrophic balance, which is important for a more ecosystem-based understanding of the estuary.

With modern continuous measurement capabilities, it is possible to also have continuous measurement of chlorophyll, and nutrients. Both are measured in discrete boat-run sampling and continuous measurements would give much more information. A parameter measured in oceanic studies that is easy to implement is the partial pressure of CO_2 (pCO_2). Paired pCO_2 measurements in air and water allow estimates of carbon flux that can quantify net heterotrophic/autotrophic balance. Several strategically placed such pCO_2 measurement stations will allow determination of the net carbon flux from the estuary.

We do have important components of an estuary-wide oxygen measurement network. Additional pieces for oxygen measurement are needed. Also continuous measurements of chlorophyll, nutrients, and pCO_2 should be considered for future capabilities.

FACILITATED WORKSHOP DISCUSSIONS

WHAT ARE THE OVERARCHING MANAGEMENT QUESTIONS IN MACOORA/DELAWARE BASIN?
Robert Tudor, Delaware River Basin Commission, Facilitator
Peter M. Rowe and Jawed Hameedi, Editors

The U.S. Ocean Action Plan calls for creation of a National Water Quality Monitoring Network (NWQMN) to advance understanding of the coastal, ocean and Great Lakes ecosystems and to support informed decision making in the management of coastal ecosystem health (coastal amenities and resources). The plan also recognizes that the NWQMN would be best implemented by establishing active linkages to the Integrated Ocean Observing System (IOOS), ideally on a Regional Association basis (For the Delaware Estuary System the regional association is Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA).).

The invited speakers presented information on existing monitoring in the Delaware River Basin and adjacent estuarine and coastal waters, and focus on water quality, sediment dynamics, and the ecological health of the estuary. These presentations set the stage for one of the specific outcomes from this workshop: Identify the overarching management questions that need to be addressed by the NWQMN in concert with the evolution of the regional IOOS infrastructure.

The workshop discussions focused on a number of themes regarding water quality management. There were concerns about setting up priorities of monitoring needs and supporting research, and whether a suitable environmental baseline exists for the watershed and estuarine waters. Typical of most other regions, there was a concern that the resource managers do not ask the right scientific questions and tend to have an unrealistic expectation that scientists will develop an information base, including models and observational technologies to address resource management issues. There was some discussion on the need for "an early warning system" for major natural and anthropogenic events in the estuary, based on set of environmental parameters and indices.

After considerable discussion, the overarching water quality-related management issues in the Delaware watershed and estuary were identified as follows:
Assessing impacts of dredging, including bottom and marshland erosion and sediment removal from non-dredged areas

1. Maintaining freshwater quantity and quality
2. Assuring public health (beach contamination, seafood safety,
3. Potential impacts of nitrogen overload and nutrient imbalance in the estuary, including factors affecting dissolved oxygen concentration in the estuarine and coastal areas Loss of habitat and population status of key species (e.g., Eastern oyster, horseshoe crab, and American shad)
4. Assessing ecological risks from of accidental discharges of oil and other chemical spills
5. Environmental sources, transport and effects of contaminants of concern in the region (e.g., polychlorinated biphenyls (PCBs), mercury, and contaminants of emerging concern such as pharmaceuticals, flame retardant chemicals, stain repellent chemicals, and industrial detergents)

In addition, there were discussions on land and resource use (habitat management) issues that focused on wetlands (areas coverage, status and health), watershed development (urban sprawl and shoreline protection), and fisheries exploitation. Land and Resource Use (Habitat Management) issues included wetlands (status, conversion and health), watershed development (urban sprawl and shorelines), sediment dynamics (dredging, navigation and wetlands subsidence), water withdrawal (freshwater inflow) effects throughout the system, and fisheries exploitation. Discussions on Climate Change focused mainly on sea level rise and its affects on coastal communities and wetlands submergence. Concerns regarding issues of Extreme Natural Events were prevalent three weeks after the devastating impacts of Hurricane Katrina along the Gulf Coast in Alabama, Mississippi and Louisiana. Concerns within the Altered Ecological Balance domain included changing food web dynamics and the impacts of invasive species. As an example of a cross cutting issue, the status of the oyster population in Delaware Bay is affected by commercial fisheries, disease, changing food web dynamics, sedimentation and variation in freshwater flow.

The following additional statements are summarized from the discussion session.

- Management goals must be defined first before identifying the stressors. A general goal could be to protect fisheries resources. Then the stressors that might be identified include overexploitation, habitat loss (essential fish habitat), diseases, and pollution or contaminants.

- The state and federal agencies have already collected a tremendous amount of data. Finding the data required can be difficult, therefore better methods are needed to access and deliver data. Additionally, do not inventory the information you do not need.

- Develop ways to utilize probabilistic monitoring with discrete monitoring in an effective and complementary manner.

- In situ monitors (real-time, continuous) are not as expensive as in the past. This is one way to include new technologies to the manager’s tool kit.

- The Delaware Estuary is fundamentally defined by its extensive fresh, brackish and saltwater marshes. The major goal of management should be to maintain and conserve the health, function and biota of the wetlands.

- The major exchange points of the Delaware Estuary include watershed inputs (Delaware River), urban inputs (Philadelphia and Camden), exchange with the Chesapeake and Delaware Canal, and exchange with the adjacent shelf.

- Nutrients are a problem in Delaware Estuary, but their management will not necessarily be the same as plans designed for the Chesapeake Bay.

- Before management can address the issues and goals for the Delaware Estuary, the ‘general public’ must find the issues and goals relevant and critically important.

SUMMARY OF BREAKOUT SESSION I: COASTAL GROUP

Scott Glenn, Rutgers University, Facilitator
Peter M. Rowe, Editor

INTRODUCTION

The purpose of Breakout Session I for the Coastal Group was threefold, to determine the: 1) the issues and needs for habitat and water quality data in the coastal/shelf area of the Delaware Estuary; 2) major data gaps in order to meet those needs; and 3) methods to assure the integration of data across a proposed linked IOOS-NWQMN Delaware Bay Region. The participants included federal, state and municipal officials, coastal managers, industry representatives and members of the academic and research communities. The Coastal Group's discussion was guided by the overall goal of the workshop to develop a framework for monitoring in the Delaware Bay region (Delaware River Watershed and Estuary and adjacent Mid-Atlantic Coastal Region) that addresses water and habitat quality related issues and that supports an Integrated Coastal Zone Management (ICZM) decision-making process.

While addressing the three challenge questions, an overarching theme emerged as highlighted by several keys or threads of discussion. These keys clearly focused on the adjacent Mid-Atlantic Coastal Region of the Delaware Bay and its connection to the Estuary through (across) physical, (geo)chemical, and biological processes:

- Key #1 Delaware River Plume
- Key #2 Boundary Conditions and Scale
- Key #3 Forecasting
- Key #4 Indicators (critters or criteria) of Impacts
- Key #5 Impacts on Habitats
- Key #6 Users

The first three keys are closely allied and set the stage for the discussions for the last three. The coastal plume is important because it connects the watershed and estuary with the coastal region by transporting freshwater, nutrients, heat, toxics, pollutants (spills) and biota out onto the shelf. Plumes may affect habitat (water column, benthos, coast [shoreline]) and is itself influenced by broader scale coastal currents (e.g., Labrador current and Hudson River plume) regional wind fields and freshwater discharge. Furthermore, plumes may bring pollutants and biota into the Estuary as demonstrated by recent LATTE observations of the Hudson plume. Therefore the boundary between ocean and estuary (bay mouth) is a significant feature for investigation. One of the needs for understanding the dynamics of the plume (and its contents) is an understanding of the boundary conditions for any models developed to describe it. Important inputs are freshwater (buoyancy) from the estuary itself and the shelf, wind fields and tidal forcing. Physically, there is much real-time data (freshwater outflow USGS, tidal height NOAA, sea surface temperature NASA/NOAA) that can be used as input for 3-dimensional circulation models of the Delaware Estuary. This may be complementary to more local operational models such as PORTS and DEOS (Delaware Estuary Observing System, maintained by Dr. Moshen Baidey at the University of Delaware) within the Delaware Estuary. However, there needs to be flexibility in both temporal and spatial scales for various user needs. Much larger temporal and spatial scales are needed to examine long term plume dynamics (weeks to months) as compared to short term needs such as attempts to forecast rip currents (days) or search and rescue (hours) using CODAR . Various models may be used to track Harmful Algal Blooms (HAB) or toxins in the plume that may affect benthic organisms (shellfish) or swimmers and surfers in the water. Thus the need for the ability to forecast the position and strength, etc. of the Delaware Estuary coastal current is a strong driver in implementing a regional linked IOOS-NWQMN pilot project. Forecasts (predictions) from monitoring input are the framework for a linked IOOS-NWQMN infrastructure.

As stated above, plumes and other coastal oceanographic (phenomenon) features have an ecological (oil spills, shellfish closures, sedimentation-benthos and affects-toxins too) and human impact. Generally, “people need to know” the causes and consequences of such phenomena on health. This need to know may be most easily seen on coastal impacts on habitats (inside Delaware Bay, coastally and back-bays) for long and short term events such as (storm flooding [e.g., USGS NJ Tide Telemetry System], erosion, rescue, sedimentation (navigation) and human health (pollutants, toxic HAB shellfish poisoning) tourism (aesthetics, recreational fishing). This led to discussions on determining indicators or criteria for ecological change or human safety. Criteria (levels) for pollutants and toxics in water column and benthos should follow as with the watershed and estuary to maintain a common language and understanding. There are concerns about sampling frequency of chemical and biotic data (usually monthly) and not ‘continuous’ real time or near real time as probably needed. Benthic and resident species would be best used as indicator species (shellfish, polychaetes, bay anchovy) for local (baywide) ecological change, while larger, migrating species (striped bass, weakfish, summer flounder) would provide ecosystem health data on a larger regional scale. As such, the ability of a linked system will provide a variety of stakeholders the capability to make decisions regarding their use of the coastal environment. These stakeholders include residents and visitors, coastal managers, research scientists, policy makers and elected officials.

SUMMARY OF RESPONSES AND COMMENTS TO CHALLENGE QUESTIONS

The facilitator guided and encouraged participation of the attendees by introducing three broad questions in regard to the coastal “geographic” section of a linked IOOS-NWQMN system for the Delaware Bay Region. A compilation of relevant comments captured during the open discussion follow.

1. What are the Water/Habitat Quality Issues and Needs Addressed by a Linked NWQMN/IOOS Infrastructure?

- A linked large scale monitoring infrastructure would support the development of a long term baseline and measurement of short term impacts (events) on local and regional (scale of Delaware Bay) changes in habitat quality and water quality.

- Some of the coastal processes affected by storm events (nor’easters, hurricanes) erosion, sedimentation, rip currents and coastal flooding.

- Forecast models based on large scale (regional) monitoring are the framework for local predictions keyed to local needs.

- The fate and transport of pathogens, organics, toxic metals, chemical (oil) spills and other pollutants, as well as hypoxia/anoxia events could be monitored for human and ecological impacts in a linked IOOS-NWQMN system.

- The above components (as well as nutrients, bacteria, suspended sediment and plankton) in the water transported from the river to estuary are transported onto the shelf in a coastal current or plume. Understanding and monitoring plume dynamics provides the ability to determine its location on the shelf, how it is transformed on the shelf, what settles out (suspended load) and what its impacts are on habitat, fisheries and beaches along the coast both in the short and long term. Additionally, plume and other shelf water and its contents routinely return to the estuary as demonstrated recently by the LATTE project investigating the Hudson River plume.

- Such a forecasting system is important, because as more people utilize the coast, the economic (tourism and aesthetics), human health and ecological impact due to beach closures from the plume transporting fecal material, oil & chemical spills, or Harmful Algal Blooms (HAB) among other things becomes significant .

- An integrated monitoring and forecasting system allows users ("People need to know.") to prepare for potential increase in hospital visits due to human reactions to sea breeze, health department preparations for selfish bed closures and Coast Guard search and rescue.

- A linked IOOS-NWQMN infrastructure would improve the ability to measure biogeochemical fluxes across the coast and shelf.

- HAB (brown/red tides) and their historic trends may be the result of human or natural variation, modulated by atmospheric deposition of nutrients.

- An integrated system will allow increased understanding of recruitment and population dynamics of keystone and indicator species (American oyster, blue crab, or resident fish species) by relating the impact of physical events, pollutants, and hypoxia, etc. on recruitment success.

- Predicted global warming will probably shrink the wide temperature range of the Mid-Atlantic Bight and result in a warmer and fresher shelf ecosystem. This may have the affect of shifting fish species distribution and thus affect commercial and recreational fisheries, as well as, increased abundances of invasive species from north and south.

- At a larger scale and different boundary conditions, climate, atmospheric conditions (sea breeze), meteorological conditions, and oceanographic processes (e.g., warm core rings impinging on the continental shelf) will influence physical and biological processes along the coast.

2. What are the Current Data (Information) Gaps?

- Determine current capabilities without adding new resources.

- Physical measurements, such as salinity, temperature and currents already provide a background for more complicated measurements.

- There is a need for high resolution models so that validation and sensitivity studies can determine the minimal quantity of data or instruments needed to suit user demands.

- Establish surface current (CODAR) and temperature mapping throughout entire system (river to estuary to shelf).

- Establish subsurface mooring systems, and ferry monitoring systems (ADCP) to sample across the mouth of the Delaware Bay in order to assess residual flow (net nontidal drift) and estuary shelf exchange.

- There is a lack of operational oceanographic systems spanning the Delaware Bay Region. Available systems to integrate include the real time PORTS system and possibly real time data generated at channel lightships through the University of Delaware (DEOS).

- We can forecast the physical oceanographic dynamics of the system due to our ability to monitor (collect) parameters such as temperature, salinity, currents, turbidity, and DO in real time or near real time in high frequency over large areas. Chemical and biological parameters are more problematic. Biological technology has to catch up.

- To fulfill our needs, other inputs required for forecasting include Chl-a, organics (PCB), bacteria, metals (Hg, Cu) and other contaminants are critical.

- There is a gap in our knowledge of indicator species available to monitor in relation to changes in physical, chemical and biological processes. There should be a strong focus on resident species, in particular benthic organisms. Data gaps exist in our biogeochemical understanding of the benthic coupling of carbon, nutrients and toxics.

- Significant data gaps exist on monitoring species that migrate into and out of the system. Collaboration between fisheries experts will improve our understanding of fish population dynamics across the larger region and perhaps increase our understanding of organic carbon transport across the estuary shelf boundary.

- A lack of a formal mechanism of needs assessment results in an information gap of criteria and data needs between scientists, coastal managers and other users. There is a need to develop a “team concept” regarding issues like erosion, dredge material and artificial beach fill. Need to be able to anticipate growing demands in boating, fishing and tourism.

3. How do we Assure Data Integration Across Regions?

- Develop an inventory of what data is being collected, from where, and in what format.

- Do not duplicate efforts of other State or Federal agencies, but find ways to enhance each others effort.

- Available data should be in a consistent format across the region; i.e., from the watershed to the continental shelf.

- There is risk of non-availability if data cannot go into standard format.

- Users, including research scientists, need a one stop website to go for both raw and summary data.

- Who will manage or own the data, or has the responsibility for data quality?

- Users need forecasting capability on website.

- Required input for a forecast model is a good organizational framework for integration across regions.

- In developing regional forecast model, determine what scientists need from managers and what coastal managers need from scientists.

- Coastal modelers require good consistent inputs of freshwater inflow for all rivers to provide reliable forecasting of coast current dynamics.

- What data from the coastal region is needed by the estuarine or watershed regions?

- Coastal modelers can forecast the physical oceanographic dynamics well using good tidal, atmospheric (wind), current, temperature and salinity data; However, forecasting chemical and biological dynamics is difficult now, especially on the small scales.

- Possible products include SST maps, current maps, and forecasts for coastal flooding, beach conditions and shellfish closures.

- Data, forecasts and other products must be in a common language that all users can understand.

- Find industry partners to develop new technologies for monitoring across the region, and develop new methodologies for data collection, access and presentation.

SUMMARY OF BREAKOUT SESSION 1: ESTUARINE GROUP

Robert Connell, New Jersey Department of Environmental Protection, Facilitator
Peter M. Rowe, Editor

INTRODUCTION

The purpose of Breakout Session I for the Estuarine Group was threefold: to determine 1) issues and needs for habitat and water quality in the Delaware Estuary from the head of the tide to the mouth of the bay; 2) major data gaps meeting those needs; and 3) methods to assure the integration of data across a proposed linked IOOS-NWQMN Delaware Bay region. The participants included federal, state and municipal officials, coastal managers, industry representatives and members of the academic and research communities. The Estuarine Group's discussion was guided by the overall goal of the workshop to develop a framework for monitoring in the Delaware Bay region (Delaware River Watershed and Estuary and adjacent Mid-Atlantic Coastal Region) that addresses water and habitat quality related issues and that supports an Integrated Coastal Zone Management (ICZM) decision-making process.

Several overarching themes (keys) emerged during the discussion of the three challenge questions. These keys focused on the Delaware Estuary (tidal freshwater to its mouth) from its connection to its watershed above the head of the tides and the adjacent Mid-Atlantic Coastal Region to the physical, geochemical and biological processes that control the dynamics of the estuary.

- Key #1 Users
- Key #2 Management and Tool Kit
- Key #3 Scaling
- Key #4 Biologic Integrity
- Key #5 Shifting Baselines

Much of the discussion by the Estuarine Breakout Group focused on the interplay of the users and management. There was a concern that users (beyond academic and management types) might not necessarily benefit significantly with the addition of IOOS type monitoring in terms of the questions users typically want answered. For example users typically want to know about the 'health' of the bay and of any fish consumption advisories. There is a need to define the rationale for monitoring, measurements and frequency of observations to the public. Management needs to decide what is to be measured before determining how IOOS-NWQMN infrastructure can address it.
Discussion also centered on the needs of the state and commonalities with neighboring states. The discourse for management also focused on how IOOS-NWQMN infrastructure could fit into a reliable management tool kit both presently and in the future, and to assess Quality Assurance and Quality Control of monitoring activities. It was suggested that it would be best to start integration of IOOS-NWQMN infrastructure on the issues most easily addressed with the infrastructure. The breakout group continued to support discrete sampling methods already in the tool kit with IOOS-NWQMN infrastructure filling in the data gaps that the older methodologies cannot or do not cover. There was a realization that there must be compatibility in sampling methods across the state(s) and federal level in order for the IOOS-NWQMN

infrastructure to provide significant gains in managements monitoring ability. Furthermore it is necessary to make sure that the focus of the new tools are on issues that they can address directly such as water quality variables and not to diverge too far past their abilities such as fish population dynamics.

There was much discussion on how the IOOS-NWQMN infrastructure could address the issue of scaling in the monitoring of the Delaware Estuary. The discussion included questions regarding the spatial and temporal scale of monitoring of even basic water parameters such as temperature and salinity. This included problems of capturing big events (storms) but also differences in parameter values from the stem of the estuary as compared to the lateral shoals and intertidal regions. A main concern is to understand the various controls on the bio-geo-chem-physical dynamics of the estuary and determine the most appropriate data collection methods. While continuous sampling methods may be best at some temporal and spatial scales, discrete sampling may be better at other scales.

The other thematic threads in the discussions were maintaining and assessing biological integrity and identifying shifting baselines in light of providing better ecosystem management. For example, there is a need to assess oyster populations in the estuary in terms of how the oysters respond to diseases and changes in salinity/freshwater inflow from short (days) to long (year) temporal scales. Additionally, how do pollutants affect food chain dynamics up to and including human consumption? There is interest in the benthic characteristics of the estuary because there is little availability in baseline data on toxic and pollutant affects on short and long temporal scales. For example, this is important so as to be able to assess changes in toxicity levels after a contaminant spill. The baseline characteristics of the Delaware Estuary have shifted since there have been changes to much of the hard benthic habitat since the decline of the oyster population. Does an IOOS-NWQMN infrastructure have the ability to address (at least indirectly) ecosystem services such as essential fish habitat?

SUMMARY OF RESPONSES AND COMMENTS TO CHALLENGE QUESTIONS

The facilitator guided and encouraged participation of the attendees through three broad questions in regards to the estuarine “geographic” section of a linked IOOS-NWQMN system for the Delaware Bay Region. The bulleted summary of the responses follow.

1. What are the Water/Habitat Quality Issues and Needs Addressed by a Linked NWQMN/IOOS Infrastructure?

- The linked infrastructure can provide long time series of salinity, temperature, currents and other geo-chemical-physical properties of the estuary.

- Through better understanding of the dynamics of atmospheric deposition, sediment transport, temperature, and salinity, etc. in the estuary, managers can improve their ability to reasonably assess the health status of living resources in the estuary.

- There is a need for better hydrodynamic and sediment transport models in order to trace the fate and transport of dissolved constituents, toxins, pollutants and oil spills.

- The infrastructure can fulfill needs for environmental information, navigation and transportation (hazards and dredging) and security needs (emergency management) that have been explicitly spelled out in USCOP.

- A Linked IOOS-NWQMN infrastructure, at least indirectly, could track short term and long term changes to: oyster populations, microbial production, primary production, and perhaps secondary production.

- The system could support the evaluation on the condition and trends in health and quality of finfish and shellfish and facilitate fisheries research.

- Improvements in decision making in regards to water flow (quantity) and water withdrawals can address the affects on the geochemistry and physics of the estuary in order to manage species of interest.

- The IOOS-NWQMN infrastructure will indirectly support ecosystem management by monitoring the factors that affect populations of interest, providing effective habitat characterization, identifying changes in food chain dynamics (particularly for bio-accumulation/magnification of pollutants), and our understanding of benthic pelagic coupling (especially in the tidal wetlands).

2. What are the Current Data (Information) Gaps?

- There are gaps in baseline data and defining natural variability so as to interpret changes in chronic-long term (toxics/pollutants) and acute-short term (e.g. oil spill) exposures to estuarine organisms.

- There is a lack of data in order to better understand fish population dynamics in relation to environmental data (ecosystem approach) as opposed to management by using catch data.

- There is a lack of data and understanding of food web dynamics in the Delaware Estuary, particularly at the microbial level, over most spatial and temporal scales.

- Our understanding of the Delaware Estuary as a whole is limited because a majority of monitoring occurs along the main stem of the estuary. This sampling is not useful for predictions (modeling) in the shallow areas of the bay in relation to toxics, sedimentation, shoal circulation, larval transport and retention, populations and various water parameters.

- Hydrodynamic models of the Delaware Estuary are robust at larger/longer scales but are not good at smaller/shorter scales and this is important for events like oil spills, etc.

- There is a lack of knowledge and need for benthic mapping (habitat characterization) and modeling in relation to point and nonpoint pollution.

- The tidal wetlands of the Delaware Estuary cannot be properly assessed unless data gaps in acreage assessment, freshwater tidal marshes, biotic inventory, sediment dynamics, shoreline erosion/accretion related to sea level rise and dredging, and wetland bio-filtering ability for water quality are addressed.

3. How do we Assure Data Integration Across Regions?

- Across the Delaware Estuary Watershed there needs to be consistency in sampling methodology (between states and federal agencies) within each geographic area that can be readily utilized by the other geographic regions.

- Data presentation must be compatible (e.g., common terminology) between the state and federal agencies and other data providers (research institutions and volunteer organization) with a reduction of data proprietary issues (a willingness to share) to allow freer access to the data.

- Rules for data suppliers should be developed so that data is available in a timely fashion for the user.

- Data should be available from one source (e.g., STORET), but users would be better served if data were made available from a regional source (e.g., MACOORA) that could promote consistency and reduce search time.

- Establish metadata file rules to document data quality and let user choose their tolerance level for the data they wish to access.

- Systems should be able to communicate using standard XML protocols.

- Develop methods (regressions or calibrations) to keep older data compatible with newer data as new technologies are developed to sample the Delaware Estuary including linkages to discrete, continuous, and spatial data.

SUMMARY OF BREAKOUT SESSION 1: WATERSHED GROUP

Eric Vowinkel, US Geological Survey, Facilitator
Peter M. Rowe, Editor

INTRODUCTION

The purpose of Breakout Session I for the Watershed Group was threefold: to determine 1) issues and needs for habitat and water quality in the Delaware Watershed (nontidal regions); 2) major data gaps meeting those needs; and 3) methods to assure the integration of data across a proposed linked IOOS-NWQMN Delaware Bay region. The participants included federal, state and municipal officials, coastal managers, industry representatives and members of the academic and research communities. The Watershed Group's discussion was guided by the overall goal of the workshop to develop a framework for monitoring in the Delaware Bay region (Delaware River Watershed and Estuary and adjacent Mid-Atlantic Coastal Region) that addresses water and habitat quality related issues and that supports an Integrated Coastal Zone Management (ICZM) decision-making process.

Several overarching themes (Keys) emerged during the discussion of the three challenge questions. These keys focused on the Delaware Estuary Watershed (non-tidal) from its connection to the tidal estuary and the adjacent Mid-Atlantic Coastal Region to the physical, geochemical and biological processes that control the dynamics in the watershed.

- Key #1 Management
- Key #2 Reduction of Data and Resources
- Key #3 Scaling
- Key #4 Real Time Monitoring
- Key #5 Shifting Baselines

The Watershed Group discussed some initial conditions for management in order to determine the appropriateness of a linked IOOS-NWQMN infrastructure for the Delaware Estuary watershed. In other words, does it meet watershed management needs and does it provide more bang for the buck? Traditional monitoring tells us "WHAT" the levels are of some parameter or impairment. It does not tell management what is causing the impairments (the "Why"). The general tone of the session suggested that it is important to address both cause ("Why") and effects ("What") during monitoring and this is key for entry into a linked IOOS-NWQMN infrastructure. Answering the "Why" will allow managers the ability to abate or reduce the impairment. Furthermore, it is important to determine the minimal needs/costs/resources to acquire the relevant data that can determine the causes of impairments in the watershed that ultimately affect the estuary downstream. This is important in light of the reduction of resources for monitoring, both manpower and collection sites, in the Delaware Estuary Watershed over recent years. This reduction is complicated by the concern that there is no clear coordination between state and federal agencies in what parameters are sampled, what methods are used and what criteria are applied for QAQC. Such fragmentation of data from current monitoring programs is an important issue to address in order to assure integration (see challenge question #3).

The reduction in sampling leads to concerns about adequate sampling in the watershed in terms of temporal and spatial scales. Much of the monitoring now occurs at a 'supersite' the Delaware River at Trenton, New Jersey and occasionally the Schuylkill River in Philadelphia, Pennsylvania. These sites can act as a proxy for the whole of the estuary downstream, but it misses the details that may determine the reason for impairments in the watershed. Variability in nutrients and toxins may be missed by not sampling laterally across the main stem of the Delaware River. Neighboring tributaries on opposite sides of the river or estuary may be of different geological type (e.g., coastal plain and piedmont) and thus behave quite differently. This information is lost by not sampling on finer scales. The group discussed the possibility of increasing sampling to higher stream level category (HUC 6 to HUC 8). Real time monitoring on short time scales was seen as a way of capturing big events in tributaries and in the Delaware River as these events send pulses of sediments and nutrients into the estuary downstream which drive changes in dissolved oxygen in concert with phytoplankton blooms. Some events may be missed because most sampling does not occur regularly at standard locations but are selected by probabilistic design. There was discussion on the relative costs of real time sampling and whether it delivered substantial benefits to managers. Because of the reduced sampling, it is difficult to determine causes for impairments and to establish baselines for evaluating the health of the aquatic system.

SUMMARY OF RESPONSES AND COMMENTS TO CHALLENGE QUESTIONS

The facilitator guided and encouraged participation of the attendees through three broad questions in regards to the watershed "geographic" section of a linked IOOS-NWQMN system for the Delaware Bay Region. The bulleted summary of the responses follow.

1. What are the Water/Habitat Quality Issues and Needs Addressed by a Linked NWQMN/IOOS Infrastructure?

- A linked IOOS-NWQMN infrastructure could address current inadequacies in sampling in order to maintain the kind of assessment needed for indicators of biological health, such as suspended sediments, nutrients, and toxics/pollutants.

- A linked infrastructure could focus dedicated sampling to one stream or river that is an important hydrologic control point to the system to better determine the fate and transport of toxics and nutrients as opposed to current monitoring that is mostly spot sampling (snapshots) that may not catch major events.

- By providing real time monitoring for managers tool kits, large events can be captured over the hydrologic curve of flow from the event and thus the understanding functional response to such events.

- Current federal programs (even defunct ones) can be used as a baseline for any newly linked IOOS-NWQMN type system that becomes available for the Delaware Watershed.

- Nearby streams in the watershed may be of different geological type and a linked monitoring system, especially in real time, could better address the differential response to major events in terms of fresh water input, the fate and transport of nutrients, nutrient loads and suspended sediments.

- An integrated monitoring system would provide managers more tools to follow the very high atmospheric deposition over the Delaware Watershed and better understand the fate and transport of mercury in the system.

- An expanded tool kit can better address management issues in regards to fish advisories on PCBs and mercury.

- With additional resources (satellites), a linked infrastructure could determine the affects of habitat fragmentation (enhanced planned use coverage for forest fragmentation and urbanization) on carbon, nutrient, and sediment loads to track landscape scale ecosystem changes and link these to biological or water quality measurements.

2. What are the Current Data (Information) Gaps?

- There are gaps in atmospheric monitoring. An estuarine site should be added to capture direct wet and dry deposition. Existing network should be supplemented to include PCBs, dry mercury and dry ammonia with universities addressing causes.

- There is an uneven distribution of freshwater biological monitoring sites between states that needs to be rectified. There needs to be an enhancement of fish communities monitoring. Utilize freshwater mussels as biological and ecosystem indicators.

- Consistent data for carbon (total and dissolved; inorganic and organic) and silica is lacking. There needs to be a better understanding of residency and transport times of dissolved constituents, pollutants and suspended sediments.

- Discharge or ambient data from the private sector is not readily available.

- A flow based network that measures loads (e.g. suspended sediments) needs to be expanded beyond the super site at Trenton? Reestablish NASQAN type sampling.

- Establish monitoring at specific sites to address trends in toxics and nutrients. There is not enough spatial data to compare river reaches. Need to increase nutrient load sampling across all states for modeling efforts (SPARROW).

- Need to re-expand and intensify ongoing trend studies with increased number of sites and increased sampling frequency for flow-weighted nutrients, pesticides, and sediments (NAWQA).

- Maintain and expand number of real-time monitoring systems and upgrade systems to collect temperature, pH, dissolved oxygen, specific conductivity, turbidity, and water flow. Add nitrate sampling when reliable and explore the addition of a real time sediment probe. There is a need to sample at a high frequency to ensure monitoring of events in real time.

3. How Do We Assure Data Integration Across Regions?

- Establish a regional server, Delaware Basin Data Exchange, as opposed to putting data into several national search databases like NWIS and STORET. Allow access to a one stop regional storehouse.

- Eliminate government fragmentation of data and increase access to it.

- Encourage all groups to share data including watershed authorities, volunteer monitoring groups, private sector, and universities.

- Develop common framework of monitoring methodologies, data presentation, terminology and definitions across the Delaware Basin so all users can readily utilize the data. For example, integrate so that data from the watershed region can be accessed by users from the estuary region. This includes real time monitoring platforms.

- Different data sets have different data quality objectives. Develop a common metafile documentation system so users can select the data that fits their criteria.

- Eliminate or reduce barriers to existing new technologies. For example, nitrate probes are not EPA certified.

SUMMARY OF BREAKOUT SESSION II: WHAT SHOULD THE FEDERALLY FUNDED BACKBONE OF IOOS AND THE NWQMN LOOK LIKE?

R. Connell, S. Glenn, and E. Vowinkel, Facilitators
(Peter M. Rowe and Jawed Hameedi, Editors)

INTRODUCTION

Breakout Session II focused on programs that might constitute the "Federally Funded Backbone" (FFB) of water quality networks and programs. Attendees were provided a list of "Principal Nationwide Water Quality Monitoring Programs" and "Examples of Ancillary Programs" that are nationwide in scope or potential. Group facilitators for each "geographic" region of the Delaware Estuary led breakout sessions to discuss which FFB programs provided monitoring support for their region. Results from the three geographic regions are reported here together.

The Federally Funded Backbone programs are described and summarized below.

I. Principal Nationwide Water Quality Monitoring Programs

1. <u>National Coastal Assessment</u>

The assessment is based on periodic data collection to document changes in values of six environmental indices. The indices are refined by filling data gaps and improving their scalability over spatial scales and robustness (statistical confidence). The temporal aspects (change or trend) of the program need to be better articulated. EPA's Coastal2000 and West Coast Pilot, with personnel and ship support from NOAA, extended coastal assessment to continental shelf waters and beyond, albeit with a smaller suite of measurements. This "offshore" assessment has regional gaps.

2. <u>National Assessment of Beaches (Beach Advisory and Closing On-line Notification)</u>

It is based on data provided to EPA by states either under BEACH (Beaches Environmental Assessment and Coastal Health) Act grants requirement or voluntarily.

3. <u>Wadeable Streams Assessment</u>

The assessment is conducted by states and consortia under grants from EPA. The program uses a stratified, random survey design that allows for extrapolation of stream condition throughout each ecological region of interest. Participants use a common biologically-based protocol and follow a comprehensive quality assurance program and standardized data management system.

4. <u>Great Rivers Assessment</u>

This assessment is designed to document current conditions in terms of water quality for three major rivers: Missouri, Mississippi, and Ohio Rivers.

5. NOAA's National Status and Trends Program – Mussel Watch

Nationwide monitoring of a suite of toxic chemicals (trace elements and organic compounds) since 1986. Provides a framework for hierarchical sampling that is appropriate to meet local and regional information needs: GulfWatch (in Gulf of Maine) and New Hampshire Mussel Watch.

6. System-Wide Monitoring Program (SWMP), NERRS, NOAA

Nationwide program focused on a few water quality parameters, including nutrients, turbidity and chlorophyll. The monitoring framework includes 27 weather and 108 water quality stations.

7. System-Wide Monitoring (SWIM), National Marine Sanctuaries, NOAA
Water Quality Protection Programs of individual sanctuaries are based on questions related to sedimentation, nutrient over-enrichment, persistent pesticides, metals, oil and grease, detergents. A system-wide monitoring strategy is currently under development (and likely to be implemented next year). In addition, a buoy-based West Coast Observations Network has recently been implemented. Presently, it consists of a few wind and ocean current related measurements; the buoys could be furnished with water quality sensors (for dissolved oxygen, fluorometry, turbidity, etc.). Currently, a 20-year monitoring plan is being thought about for the Monterey Bay National Marine Sanctuary, the largest sanctuary encompassing coastal and ocean areas (nearly 14 thousand square km) extending to a depth of 3.25 km.

8. US Marine Observations Backbone

This NOAA-supported system is comprised of data distribution from a variety of moored buoys and coastal stations, many of which are automated. In addition, the system provides data from Voluntary Observing Ship (VOS) program, Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoy array, and other NOAA. The data can be obtained from the National Data Buoy Program Office website or using the Dial-a-Buoy telephone call.

9. CASTNet

Clean Air Status and Trends Network, principally funded by EPA, provides data on concentration and dry deposition of a number of air pollutants. It consists of 70 monitoring sites throughout the country. The monitoring data are also used to verify modeled concentrations, based on dry deposition velocities estimated from meteorology, land use, and site characteristic data. The need for "intensive monitoring" to support the scientific study of ecosystem processes is also noted by the US COP (Chapter 15).

10. National Atmospheric Deposition Program (NADP) / National Trends Network (NTN)

The program, cooperatively implemented by dozens of partners, collects data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. The precipitation at each station is collected weekly according to strict clean-handling procedures. It is then sent to the Central Analytical Laboratory where it is analyzed for hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium).

11. USGS National Water Quality Assessment (NAWQA) Program

The National Water Quality Assessment (NAWQA) Program of the U.S. Geological Survey is designed to assess historical, current, and future water-quality conditions in representative river basins and aquifers nationwide. One of the primary objectives of the program is to describe relations between natural factors, human activities, and water-quality conditions and to define those factors that most affect water quality in different parts of the Nation. The NAWQA Program's unique design provides consistent and comparable information on water resources in 60 important river basins and aquifers across the Nation.

12. USGS National Stream Quality Accounting Network (NASQAN)

The National Stream Quality Accounting Network (NASQAN) of the U.S. Geological Survey, originally established in 1974, to establish baseline levels of water quality parameters, including nutrients, major ions and suspended sediment, for the Nation's major rivers and streams. Since then, the Network has undergone major changes in its scope and design due to budget constraints or priorities. In 1995, the Network focused on monitoring the water quality of the nation's largest rivers--the Mississippi (including the Missouri and Ohio), the Columbia, the Colorado, and the Rio Grande and later, beginning in 2001, it entered a five-year special study phase that included significantly decreasing sampling in two basins, the Colorado and Columbia, and redirecting resources to an intensive sampling program in the Yukon River basin.

13. Monitoring and Event Response from Harmful Algal Blooms (MERHAB)

This NOAA-managed program provides funding for long-term monitoring of specific toxins in the food web, development of new (including molecular) techniques to detect HAB species in the natural environment, development of new sampling protocols, and ecological forecasting. Much of the work being done is on "regional basis."

II. Examples of Ancillary Programs (Nationwide in scope or potential)

1. CoastWatch

NOAA's CoastWatch program, consisting of Central Operations and six regional nodes, processes satellite-derived data and provide oceanographic products to Federal, State and local marine scientists, coastal resource managers, and the general public. For instance, temperature images are used to locate fishing spots and for forecasting weather. Ocean color images help scientists track biological changes in the ocean, while sea surface wind images are used primarily by meteorologists and boaters. Data are processed near real-time, therefore are usually only a few hours old.

2. Physical Oceanographic Real-Time System

Located in major U.S. ports, PORTS provides integrated, real-time information products from observations on winds, water levels, currents, tides, and visibility to enhance safety and efficiency of maritime commerce. Water quality sensors can be mounted on PORTS buoys.

3. National Water Level Observation Network

This is a network of tide and water level gauges installed all along the U.S. coastline, bays and estuaries. It also provides a long-term record of water levels measurements dating back to the 1850s.

4. Topographic Change Mapping Program

The program analyzes high-resolution topographic and other spatial data sets to derive current status and changes in coastal physiography and dune field topography. Period of record starts in 1996.

5. Land-Cover Change Analysis Program

The program is developing a standardized database of land cover and habitat change (over a five-year period) in coastal regions. Period of record starts in 1990.

6. NSF's Long-Term Ecological Research (LTER)

This program supports investigations of whole ecosystems and their components and processes at sites that represent major biomes.

7. Coastal Intensive Site Network (CISNet)

This NOAA/EPA/NASA pilot project was developed to test a series of environmental indicators to track changes in major environmental stressors and to relate those changes to observed effects on the ecosystem structure, function and services. The program is probably defunct now, but the need for such sites has been recommended by NSTC since 1996 (as "Index Sites").

8. National Health and Nutritional Examination Surveys (NHANES)

The monitoring program, conducted by Centers for Disease Control and Prevention, provides information on levels of environmental chemicals measured in human tissues. The chemicals include metals, such as lead, mercury, pesticide metabolites, phthalate metabolites, and cotinine (a marker for tobacco smoke).

9. National Listing of Fish Consumption Advisories

EPA provides a listing of fish consumption advisories and safe eating guidelines each summer based on information produced by states, territories and tribes. In the year 2003, it listed 3,089 advisories based on fish tissue contaminant data from 46 states and the District of Columbia.

SUMMARY

Each breakout group found many FFB monitoring programs that supported or had the potential to support a linked IOOS-NWQMN infrastructure in their region (Table 1). However, many of these programs did not cover the Delaware Estuary System (e.g., GSA), had limited coverage (e.g., WSA), or were covered in the past (e.g., NASQAN).

The Watershed group listed other programs that could support a linked infrastructure in their region. These included EMAP (Environmental Monitoring and Assessment Program; an EPA research program that develops the tools necessary to monitor and assess the status and trends of national ecological resources), MAIA (Mid Atlantic Integrated Assessment; EPA program that provides integrated scientific knowledge to support the environmental decision-making process for the Mid-Atlantic region), CEMRI (Collaborative Environmental Monitoring and Research Initiative; looks at effects of terrestrial ecosystem health and land use on hydrology, habitat and water quality), SPARROW (SPAtially Referenced Regressions On Watershed; models nutrient load data), BEST (Biomonitoring of Environmental Status and Trends; USGS program and source of PCB data) and IADN (Integrated Atmospheric Deposition Network).

The Estuary group was able to make the most extensive use of the monitoring programs presented as FFB programs. They also included EMAP in their needs as well as requiring data support from the National Weather Service (NWS). CO-OPS (Center for Operational Oceanographic Products and Services) is the portal to NOAA's collection of oceanographic and meteorological data (historical and real-time), predictions, nowcasts and forecasts.

The Coastal group focused their attention on programs that provided forecasting. These programs would provide the framework to make predictive model for the Delaware Bay and its coastal region. As with the other breakout groups the coastal group included CO-OPS, NWS, EMAP and MAIA as supportive federal programs beyond the core programs listed in Table 1. However, they went further to obtain tidal information from NOAA's National Ocean Service (NOS) and atmospheric and oceanographic data from NOAA's National Buoy Data Center (NBDC). The National Estuarine Research Reserve System (NERRS) also collects atmospheric and estuarine data. USGS provides flow data from river gauges through its National Water Information System (NWIS). Through NASA, geostationary satellites can provide sea surface temperature data. Additionally, the Global Ocean Data Assimilation Experiment (GODAE) sponsored by the Office of Naval Research provides regular, complete descriptions of the temperature, salinity and velocity structures of the ocean in support of operational oceanography.

Table 1. *Federally funded monitoring programs that provide support or potential support for each of the three geographic regions (Watershed, Estuary and Coastal) of the Delaware Estuary System.*

	Program	Watershed	Estuary	Coastal
Principal Nationwide Water Quality Monitoring Programs				
1	NCA		X	X
2	NAB		X	X
3	WSA	X		
4	GSA			
5	NSTP		X	
6	SWMP		X	
7	SWiM			X
8	USMOB		X	
9	CASTNet	X	X	
10	NADP/NTN		X	
11	NAWQA	X	X	
12	NASQAN	X	X	
13	MERHAB		X	X
Ancillary Programs (Nationwide in scope or potential)				
1	CoastWatch			
2	PORTS		X	X
3	NWLON		X	
4	TCMP			
5	LCCAP			
6	LTER		X	
7	CISNet		X	
8	NHANES			
9	NLFCA		X	

DESIGN OF A PILOT STUDY

Jawed Hameedi, NOAA, National Centers for Coastal Ocean Science, Facilitator
Jawed Hameedi and Peter M. Rowe, Editors

The primary focus of discussion was development of an effective observing program for the Delaware River and Bay (Delaware Estuary) that will protect and enhance its many functions. The observing program is envisaged to consist of a coordinated, comprehensive monitoring network that will rapidly provide information for the diverse "managers" of the estuarine uses and resources. The network will involve multiple users and employ state of the art science and technology. The network will integrate across watershed, estuary, and the adjacent coastal ocean. Only upon implementation of such strategic design and coupling of observational data with research and modeling capabilities, would it be possible to assure effective stewardship and to be prepared for natural and man-made episodic events that could cause loss of the resources and amenities of the estuary.

Specific objectives of such a program could include the following:

- Link among existing monitoring programs administered by an array of regional, state and local programs and the National Water Quality Monitoring Network (NWQMN).
- Integrate data from discrete sampling throughout the estuary and continuous measurement installations at locations along the estuary.
- Make application of IOOS type measurements to watershed, river, estuary, and coastal regions.
- Develop and deploy new real-time sensors.
- Provide the information from this observing system for ecological forecasting and environmental prediction models.
- Provide real-time data from the observing system for emergency management.
- Use experience from this pilot effort to assist in developing similar IOOS systems within the MACOORA region.
- Use examples from this pilot effort for application in other regions of the US.

Although it has long been regarded as an industrial system, the Delaware Estuary is also regarded as a national environmental asset containing a wealth of natural features and living resources. For example, it contains one the longest un-dammed stretches of a large river in North America, one the world's largest freshwater tidal estuaries, and numerous keystone species (horseshoe crabs) and habitats (tidal marshes) that are not as prominent in other mid-Atlantic systems. All major forest types of the Eastern U.S. are represented within the watershed.

The drainage basin of the Delaware Estuary provides one of the largest drinking water supplies in the US, the greater Philadelphia area is one of the largest port complexes in the US, the tidal river houses the fourth largest greater municipal region in the US, the brackish and fresh water upper reach houses one of the largest hubs of oil refinery and chemical industries in the US, and the lower estuary is highlighted by extensive wildlife habitats and refuges. Finfish and shellfish remain important commercial resources in Delaware Bay.

The Delaware Estuary region is noted for excellent academic and research institutions, many of which have actively participated in addressing resource management issues. Institutions such as Rutgers University and the University of Delaware are among the leaders in the development and application of measurements technologies and platforms in the coastal and oceanic environments. In addition, there has been successful cooperation among the four states in the drainage basin through the Delaware River Basin Commission and coordinated management among the three estuary region states through the Delaware Estuary Program. A good beginning exists for a cooperative monitoring capability.

The Delaware Estuary is an ideal location for a pilot IOOS which could later be expanded to other systems in the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA). Due to advantages offered by the Delaware Estuary, an IOOS-NWQMN pilot project would also serve as a national example. For the combination of drainage basin area and multiple uses and of the estuary's resources, it could be argued that no other estuary is more vital to the US economy. In addition, due to dominance by a single river and a geometric regularity to the estuarine shape, the Delaware is an easier system to monitor thoroughly and to model.

In the plenary presentation at this workshop, "New and Emerging Monitoring Technologies – Physical and Chemical Remote Sensing and Biological Measurements", Dr. Antonio Baptista (OGI School of Science and Engineering, Oregon Health & Science University) highlighted some of the aspects of a currently operational web-based integrated monitoring system. The NANOOS (Northwest Association of Networked Ocean Observing Systems) pilot (www.nanoos.org) links coastal and water quality applications of IOOS-type measurements for Washington and Oregon estuaries. More specifically, Dr. Baptista concentrated on CORIE, a pilot environmental observation and forecasting system (EOFS) for the Columbia River (www.ccalmr.ogi.edu/CORIE/). The system integrates a real-time sensor network, a data management system and advanced numerical models that characterizes and predicts the circulation and mixing processes of the Lower Columbia River including the estuary and the adjacent coastal ocean. The system is designed to provide objective insights on the spatial and temporal variability of the Lower Columbia River; to advance the emerging field of environmental information systems and the understanding of river-dominated estuaries and plumes; and to provide natural resource management and regulation community powerful new planning and analysis tools to improve policies and decisions. Dr. Baptista offered to provide the CORIE framework as a template for a Delaware Estuary pilot EOFS.

The following list summarizes the statements from the workshop participants on the needs and actions required to begin a preliminary but integrated pilot study for the Delaware Estuary System:

- Accept the offer from Dr. Baptista to utilize his template for our pilot study and obtain an understanding of the success of his program.

- For the initial model, select one or two parameters that are well studied, have ample data that can be readily integrated and are readily compatible with other data sets. Other parameters can be added later.

- Dissolved oxygen (DO) and Total Suspended Solids (TSS) were the most suggested parameters.

- Incorporate both discrete and continuous (real time) sampling of DO into model and tie to DO in the Delaware Estuary wetlands.

- Develop a proposal and shop around to potential interested parties and potential funding sources, in particular MACOORA.

- Design pilot study so that it can link to other systems in the MACOORA region.

- "Sell" pilot study by highlighting the benefits to integrating existing data and define the unique role an EOFS can contribute to the Delaware Estuary and its inhabitants.

- Make issues that can be addressed by the pilot project relevant to prospective funders. For example, link DO and nutrients to HAB, show connection between TSS and toxics, and negative impacts of storm events.

- The pilot project should include research, forecasting, technology transfer and have an educational and outreach component.

- Need to identify and fill gaps in current models of the Delaware Estuary System and incorporate the advantages of the COOPS and PORTS models.

- The website that houses the pilot project should be started and maintained by a single or institution for rapid response to any changes.

- Form small working groups to 1) work with Dr. Baptista on developing a template for the Delaware estuary; 2) develop the website and select one location to house it; and 3) shop the proposal to interested parties.

- The pilot study should include new technology as it arises and develop useful products (including hindcasts and forecasts) to dissemination to the public and private sector.

- Develop a long term vision for the pilot project incorporating themes of 1) the integration from the watershed to the coast; 2) forecasting ability; and 3) response to sea level rise.

SUMMARY AND CONCLUSIONS

Peter M. Rowe and Jawed Hameedi

Improved scientific understanding of the coastal, oceanic and Great Lakes ecosystems and improved public understanding of its environmental stewardship responsibilities are both essential for making effective decision to protect and restore water quality conditions in the Nation. At the minimum, this would require coordination of efforts among the principal federal agencies involved in water quality monitoring, contacts with states, regional organizations and tribes about their specific needs, and an efficient systems of data gathering and dissemination. The U.S. Ocean Action Plan (December 2004) called for the design and creation of a coordinated, comprehensive National Water Quality Monitoring Program that addresses those needs is also effectively linked with the Integrated Ocean Observing System (IOOS). In response, two separate but highly significant national efforts are presently (2006) underway to develop a conceptual design of (1) a National Water Quality Monitoring Network (NWQMN) and (2) the Integrated Ocean Observing System (IOOS). The NWQMN, intended as a "network of networks" shares many attributes with existing water quality monitoring programs but is unique in that it provides for a multi-disciplinary and multi-institutional approach and offers both continuity of observations, i.e., from the watershed to the coastal ocean, and connectivity with likely sources of contaminants, for example, atmospheric deposition, groundwater discharge and coastal rivers and tributaries. The NWQMN design report is expected to be completed in April 2006. A development plan for IOOS was recently published by the National Office for Integrated and Sustained Ocean Observations (January 2006) and contract was recently issued to further develop and refine a (i) conceptual design of IOOS, (ii) an estimate of the cost to produce the system based on the conceptual design, and (iii) a narrative explanation of the viability of the design. It is anticipated that a recommended "National Backbone" of measurements, consisting of core measurements required by broad spectrum of users and with common protocols for data management and dissemination, will be shared by both IOOS and NWQMN.

Both IOOS and NWQMN consider pilot projects to demonstrate application of exiting technologies and capabilities in addressing water quality issues in a selected region of interest. One outcome of such projects would be an assessment of strengths and weaknesses of the architecture of a comprehensive monitoring program, for example, the design of the NWQMN, an evaluation of data management infra-structure, and demonstration of the efficacy of current monitoring approaches, procedures and technologies for addressing specific, regional issues that pertain to water quality.

The National Oceanic and Atmospheric Administration (NOAA) hosted a workshop to explore potential linkages and areas of commonality between IOOS and NWQMN designs that could be linked and utilized for providing the data and information products necessary for preserving and enhancing water quality conditions in the U.S. coastal waters and estuaries. The workshop, held at Rutgers University from September 19 to 21, 2005, was organized in partnership with the newly formed Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA), U.S. Geological Survey, Rutgers University, and the New Jersey Sea Grant College Program. Workshop attendees included federal, state and municipal officials, coastal managers, members of academic and research institutions, and industry representatives.

The workshop focused on elucidating the water-quality related resource management assets and on the development of a regional pilot network for water quality monitoring (physical, biological and chemical parameters) that links IOOS data to integrated coastal zone management (ICZM) decisions affecting sustainable uses, and the health of coastal ecosystems. As background for this initiative, invited speakers provided information on the existing monitoring both nationally and in the Delaware Estuary System. Barry Burgan (U.S. Environmental Protection Agency) summarized the National Coastal Assessment (NCA), an integrated, comprehensive monitoring program designed to evaluate methods to advance the science of ecosystem condition monitoring. The second National Coastal Condition Report (NCCR II) graded the overall condition of the nation's coastal waters as fair, based on water quality, coastal habitat loss, sediment quality, benthic community condition, and fish tissue contaminants. Eric F. Vowinkel (U.S. Geological Survey) focused on water-quality monitoring in watersheds above the head of tide in the Delaware River Basin. He noted that because of the uncoordinated monitoring and data storage by various groups in the watershed, determining sources, loads, and environmental effects of contaminants is difficult. Robert Connell (New Jersey Department of Environmental Protection, Water Monitoring and Standards, Bureau of Marine Water Monitoring) described several of the programs performed by the state agency to monitor all coastal water quality, mainly for public health concerns through compliance with the National Shellfish Sanitation Program. A growing network of real-time water quality sensors placed in New Jersey's coastal and bay waters complement the traditional monitoring program.

Christopher Sommerfield (University of Delaware, College of Marine Studies) discussed the long history of sediment management in the Delaware Estuary. In order to address current and future latent problems, environmental managers, engineers and researchers require system-wide time series measurements of water properties to facilitate trend analysis and predictive modeling. Scott Glenn, Oscar Schofield and Robert Chant (Rutgers University, Institute of Marine and Coastal Sciences) described the Mid-Atlantic coastal shelf ecosystem observatory, components of which can be made applicable to the Delaware Estuary. Current upgrades of the cabled network will facilitate the system's integration into the broader national landscape of national ocean observing systems. Jonathan Sharp (University of Delaware, College of Marine Studies) provided details on long-term water quality monitoring in the Delaware River and Bay that address ecosystem responses to dissolved oxygen and nutrients. Although long-term trends in dissolved oxygen have shown improvements, there are concerns that decreases in oxygen in the tidal river could re-occur in the future from increasing excess algal production. Finally, although not presented as a summary paper in this proceedings, Antonio Baptista (OGI School of Science and Engineering, Oregon Health & Science University) provided highlights of the NANOOS (Northwest Association of Networked Ocean Observing Systems) pilot program and CORIE, a pilot environmental observation and forecasting system (EOFS) for the Columbia River. This overview provided the attendees a glimpse of the possibilities for an integrated NWQMN-IOOS monitoring network for the Delaware Estuary System.

The presentations by the invited speakers provided a framework for the identification of the overarching management questions that need to be addressed by the NWQMN in concert with the evolution of the regional IOOS infrastructure. For any integrated management system there needs to be a centralized effort that is able to coordinate and overcome the fragmentation of federal and state government agencies. The overarching management issues for the Delaware

Estuary System were Pollution and Contamination, Land and Resource Use, Climate Change, Extreme Natural Events, and Altered Ecological Balance. More specifically, the Delaware Estuary is framed by extensive fresh, brackish and saltwater marshes, thus an important goal of management should be to maintain and conserve the health, function and biota of the wetlands.

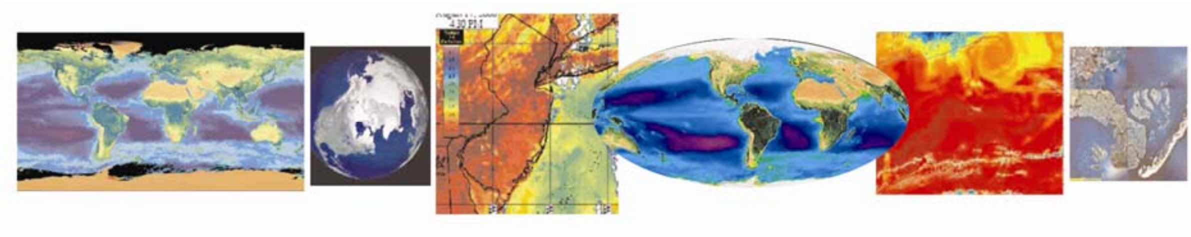
The design of a regional pilot will provide integrated sampling coverage in coastal, estuarine and watershed waters to promote compatibility and comparability of the monitoring results. Breakout sessions in these three 'geographic' areas addressed the following four challenge questions: What are the water/habitat quality issues and needs addressed by a linked NWQMN/IOOS Infrastructure; what are the current data gaps; how do we assure data integration across regions; and what should constitute the Federal backbone of water-quality related monitoring programs? Several themes or threads ran through the discussion of these questions. All groups were concerned about the ability of managers to define what to measure and at what temporal and spatial scales, and in what format of information products most appropriate for decision making. Finally, discussions took into consideration how to address biotic integrity and habitat impacts within the context of shifting environmental baselines. In general, an integrated monitoring system, at the proper spatial and temporal scales, including real-time (continuous) data collection, would minimize data gaps and improve information products designed to forecast and respond to natural and anthropogenic stressors. Comparable and compatible data should be available on a regional server (Delaware Estuary System) housed at one location, supported by government, academic, private sector and volunteer groups, and should be user driven such that the user determines the criteria level needed for their investigation based on information provided in metafiles.

For the fourth challenge question, each 'geographic' group established that at least some of the 'federally funded backbone' programs would be useful in generating and supporting an integrated monitoring system. Some of these included National Coastal Assessment (NCA), National Water Quality Assessment (NAWQA), National Stream Quality Accounting Network (NASQAN), Monitoring and Event Response from Harmful Algal Blooms (MERHAB), National Status and Trends Program (NSTP) and Physical Oceanographic Real-Time System (PORTS). However, several of the programs do not cover the Delaware Estuary System, have been terminated or have only limited or reduced coverage. The breakout groups suggested that additional programs and agencies should support an integrated monitoring system in the region, most notably through observational programs in NOAA, USGS, NASA and the EPA. Examples of such programs include MAIA (Mid Atlantic Integrated Assessment), EMAP (Environmental Monitoring and Assessment Program) and CO-OPS (Center for Operational Oceanographic Products and Services)

The final session of the workshop focused on the design of a pilot study for the Delaware Estuary System that links IOOS data and product development to integrated coastal zone management (ICZM) decisions affecting sustainable uses, and the health of coastal ecosystems. The chapter "Design of a Pilot Study" in this proceeding provides the foundation for the conclusion and recommendations for this chapter.

There has been substantial research and monitoring in the Delaware Estuary System. However, it has been uncoordinated and fragmented among many state and federal government agencies, as well as academic and research institutions. It was strongly suggested by the workshop participants that entities must be willing to pull their resources, knowledge and expertise together under one umbrella in order to answer questions that can only be addressed by an integrated monitoring system. This combined network will require increased sampling/monitoring at the proper spatial and temporal scales and include the use of real-time monitoring, plus the flexibility to add new technologies as they arise. As the 'geographic' breakout groups noted, this can only be accomplished through a "common universal language" across all geographic regions. The ever-present lack of funds appears to be the major drawback for linking elements of IOOS with the planned NWQMN to create a pilot network for the Delaware Estuary System. The following recommendations were made to increase the likelihood for funding. Identify issues that can be addressed by the pilot project and are relevant (provide benefits) to prospective funders, in particular MACOORA. Select one parameter that is well studied, and has ample data that can be readily integrated and is readily compatible with other data sets (dissolved oxygen). Utilize current pilot projects as a template and design to link with other systems. These actions support the consensus of the workshop participants that with increased collaboration of all participating entities, an integrated observing system can be developed and activated for the Delaware Estuary System.

APPENDIX A—WORKSHOP AGENDA



Linking Elements of the Integrated Ocean Observing System (IOOS) with the Planned National Water Quality Monitoring Network

FINAL WORKSHOP AGENDA

19-21 September 2005
Cook College Campus, Rutgers University

Day 1 (Monday)

11:00-12:00	**Registration and Refreshments** (Cook Campus Center – Room 202)
12:00-1:30	**Welcome Remarks and Luncheon** – *Dr. Peter M. Rowe*, Associate Director, New Jersey Sea Grant College Program; *Dr. Keith Cooper*, Research Dean, Cook College
1:30-2:00	**Background and Expectations from the Workshop** - *Dr. Jawed Hameedi*, NOAA
2:00-3:30	**Existing Monitoring in Delaware Bay** *Mr. Ed Santoro, DRBC – Facilitator* (Panel Speakers: *Dr. Barry Burgan*, USEPA; *Dr. Eric Vowinkel*, USGS; *Mr. Bob Connell*, NJDEP, *Dr. Chris Sommerfield*, University of Delaware; *Dr. Jonathan Sharp*, University of Delaware)
3:30-3:45	**Break**
3:45-5:30	**Group Discussion: What are the Overarching Management Questions in MACOORA/Delaware Basin?** (*Mr. Robert Tudor* - Facilitator)
5:30-6:30	**Check-In and Break Period**
6:00 - 7:00	**Cocktail Hour,** Light Snacks (University Inn & Conference Center)
7:00 - 7:45	**IOOS Slide/Web Presentation** - *Dr. Scott Glenn and Dr. Robert Chant,* Rutgers University
7:45 - 8:00	*Dr. Frederick Grassle*, Rutgers, Introductory Remarks, Introduce Robert Carullo representing *Congressman Curt Weldon*
8:00–9:00	**Dinner Served** - Plenary Remarks, *Robert Carullo, Executive Director, Strengthening the Mid-Atlantic Region for Tomorrow (* SMART) (before dessert)

NEW JERSEY MARINE SCIENCES CONSORTIUM · RUTGERS · Sea Grant New Jersey · USGS · NOAA · MACOORA

Day 2 (Tuesday)

7:30-8:30 **Continental Breakfast** (IMCS – Alampi Room)

8:30-9:30 **Plenary - New and Emerging Monitoring Technologies – Physical and Chemical Remote Sensing and Biological Measurements**
Dr. Antonio Baptista, OGI School of Science and Engineering, Oregon Health & Science University

9:30-12:30 **Breakout Session 1*** (IMCS – Rooms: Alampi, 203, 105, 103)

- What are the Water/Habitat Quality Issues and Needs Addressed by a Linked NWQMN/IOOS Infrastructure: Uplands, Estuaries, and Coastal Zone
- What Are the Current Data Gaps?
- How do we Assure Data Integration Across Regions?

- NOTE: Breakout Session 1 (3 hours) shall consist of three separate groups addressing each of the three questions and will include Management, Education, and Outreach personnel and representatives from the Physical, Biological and Chemical disciplines. Breakout groups will be separated by "Geography" - Watershed (Facilitator – *E. Vowinkel*, Estuary (Facilitator – *R..Connell*) and Coastal Zone (Facilitator – *S. Glenn*).

"Geography"	Monitoring Type					
	Manager	Educator	Outreach	Physical	Chemical	Biological
Watershed (15)	1	1	1	4	4	4
Estuary (15)	1	1	1	4	4	4
Coastal Zone (15)	1	1	1	4	4	4

12:30-1:30 **Lunch**

1:30-3:00 **Breakout Session 2A**** (IMCS – Rooms: Alampi, 203, 105, 103)
(3 facilitators: *E. Vowinkel, R. Connell* and *S. Glenn*)

- What Should the Federal Backbone of IOOS and the NWQMN Look Like?

**Note: Educators and outreach coordinators will meet separately in Session 2B

1:30-3:00 **Breakout Session 2B** (IMCS – Rooms: Alampi, 203, 105, 103)

- What are the Outreach/Education Needs?
  Note: Educators/Outreach Personnel only!

3:00-5:00 **Report Backs and Synthesis Across Groups** (IMCS – Alampi Room)
(Timing of Break at Discretion of Facilitator: *J. Hameedi*)

5:00-6:00 **Tours of Rutgers "Cool Room",** *Dr. Scott Glenn*

6:30 **Dinner** (On your own)

Day 3 (Wednesday)

8:00-9:00 **Continental Breakfast** (IMCS – Alampi Room)

9:00-11:30 **Design of a Pilot Study – Delaware River, Bay and Shelf**
(Facilitator - *J. Hameedi*)

11:30-12:00 **Workshop Summary - Action Items and Next Steps** (*J. Hameedi*)

12:00 Adjourn

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