CBNERRVA Research and Monitoring Program

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ABSTRACT

The overall goal of the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERRVA) research and monitoring program is to promote, coordinate and conduct research and monitoring to enhance the scientific understanding and management of the York River and southern Chesapeake Bay coastal ecosystems. The regions of greatest scientific emphasis are located within four Reserve sites located along the York-Pamunkey River estuarine system. Primary research and environmental monitoring areas include: estuarine and shallow water environments including benthic communities, submerged aquatic vegetation and emergent wetlands habitats, open water regions and adjacent watersheds and air sheds. Both national priority (NOAA) and Chesapeake Bay specific (Chesapeake Bay Program) research focus areas are pursued within the Research Reserve with goals to: enhance scientific understanding of coastal ecosystems, surrounding environments and the natural and human processes influencing such systems; and, promote the effective management and conservation of natural and cultural coastal resources through informed decision-making. A System-wide Monitoring Program (SWMP) initiated by the Estuarine Reserves Division (ERD) of NOAA provides standardized data on national estuarine environmental trends through similar measurements of abiotic and biotic variables as well as watershed and land use classifications and measurements at each of the 27 Reserves. Data are compiled electronically at a central data management location and are available via web interface (www.vecos.org). Ongoing York River monitoring programs at the CBNERRVA reserve sites include; meteorological and streamflow monitoring, water quality monitoring and biological monitoring are available through the Reserve or via web interface. Multi-parameter water quality, in situ monitors at both fixed and buoyed stations, point sampling and continuous underway flow-through monitoring form the basis of the water quality monitoring program. Research opportunities at Reserve sites are available to any qualified scientist, academician or student affiliated with a university, college or school, non-profit organizations, and non-academic research institutions. In addition, the Reserve sponsors competitive graduate research fellowships through the NERRS Graduate Research Fellowship (GRF) Program for student research in the York River system.

GENERAL APPROACH

The overall goal of the CBNERRVA Research and Monitoring Program is to promote, support, coordinate, and engage in research and monitoring efforts that enhance scientific understanding of estuarine and watershed ecosystems and associated processes and functions, and to communicate results of research to assist in environmental education and wise stewardship of coastal resources. Enhancing scientific understanding of the York River and southern Chesapeake Bay coastal ecosystems, surrounding environments and the natural and human processes influencing systems requires a broad range of expertise and capabilities. In order to contribute to this increased understanding, the Reserve pursues a variety of approaches including:

- Encouraging, and where possible supporting, research and monitoring by individual investigators or groups with emphasis given to those addressing Reserve priorities;
- Collaborating with individual investigators or groups conducting research and related monitoring within the York River and Bay region;
- Developing in-house research and monitoring programs led by CBNERRVA associated faculty and senior staff; and
- Collecting, synthesizing and publishing/disseminating available information.

The region of scientific emphasis is focused within the four Reserve components, it also extends beyond Reserve boundaries to include the entire York River system, which includes the Pamunkey and Mattaponi Rivers, its watershed, and water regions that affect or are affected by the York River system. Extending beyond Reserve component boundaries is necessary to address large-scale processes that influence the York River system and allows for collaborative efforts with other individuals or entities responsible for complimenting research and monitoring programs. This collaborative effort results in more integrated and comprehensive research and monitoring programs for the Reserve and other Bay-wide groups.

There are typically 30 or more research and monitoring oriented projects conducted on an annual basis by researchers from a variety of state and federal agencies, academic institutions, and private consulting firms within Reserve boundaries. Primary research and environmental monitoring focus areas conducted by CBNERRVA scientists include:

- Ecology and management aspects of estuarine and coastal shallow water environments, with an emphasis on benthic communities including submerged aquatic vegetation, and emergent marshes, water column processes and physical conditions (e.g. waves, currents and water depth);

- Watershed and airshed material flux into coastal waters;
- Ecological impacts of large-scale episodic events, long-term climatic changes and sea-level rise; and
- Participation in the development and implementation of local (Virginia Estuarine and Coastal Observing System), Bay-wide (Chesapeake Bay Observing System), and regional (Mid-Atlantic Coastal and Ocean Observing Regional Association) observing systems.

NATIONAL PRIORITY RESEARCH FOCUS AREAS

NOAA has recently redesigned its approach to research by moving towards a more interdisciplinary, cross-cutting strategy to address identified priority research areas (NOAA 2005). The new infrastructure for NOAA's research focuses on four broad mission goals: (1) Ecosystems, (2) Climate, (3) Weather and Water, and (4) Commerce and Transportation. NERRS is a primary contributing member of the Coastal and Marine Resources Program within the Ecosystems Goal Team. The mission of the Ecosystems Goal is to protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management. Additionally, NERRS also contributes to the Climate Goal and Weather and Water Goal. NERRS has identified the following five priority research areas to complement the funding priorities outlined above:

- Habitat and ecosystem processes;
- Anthropogenic influences on estuaries;
- Habitat conservation and restoration;
- Species management; and
- Social science and economics.

Currently, there are two reserve system-wide efforts to fund priority estuarine research. The Graduate Research Fellowship Program (GRF) supports students to produce high quality research which addresses relevant focus areas in the reserves. Secondly, research is funded through the Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), which will transition into the National Coastal and Estuarine Research and Technology (NCERT) Program, which supports development and application of tools to enhance understanding and management of coastal ecosystems.

CHESAPEAKE BAY RESEARCH FOCUS AREAS

In addition to the national funding and programmatic priorities, NOAA recognizes that individual reserves develop, support, and implement site-specific research programs to address local and regional research and management needs. In 1983, Virginia, Maryland, Pennsylvania, the District of Columbia, the USEPA and the Chesapeake Bay Commission formally agreed to coordinate interstate planning and programs for the Chesapeake Bay and its tributaries and establish mechanisms to facilitate that coordination. Since 1983, this joint commitment has led to new levels of government cooperation, including a more comprehensive Chesapeake Bay Agreement by the Chesapeake Executive Council in 1987, which accelerated advances in the Bay's restoration and protection. To address data and information gaps, the Chesapeake Executive Council developed a Comprehensive Research Plan for the Chesapeake Bay (Chesapeake Executive Council, 1988).

In June 2000, Chesapeake Bay Program partners adopted the Chesapeake 2000 Agreement, a strategic plan to achieve a vision for the future of the Chesapeake Bay (Chesapeake Bay Program, 2000). A vision that includes abundant, diverse populations of living resources, fed by healthy streams and rivers, sustaining strong local and regional economies, and our unique quality of life. Chesapeake 2000 is one of the most aggressive and comprehensive watershed restoration plans ever developed. The agreement is the result of a comprehensive three-year stakeholder-driven process involving more than 300 scientists, resource managers, policymakers and citizens from all parts of the Bay watershed. Restoration of an ecosystem as complex as the Chesapeake Bay requires work on many fronts. The agreement details nearly one hundred commitments important to Bay restoration, organized into five strategic focus areas:

- Protecting and Restoring Living Resources - Chesapeake 2000 aims to restore, enhance and protect the finfish, shellfish and other living resources, their habitats and ecological relationships to sustain all fisheries and provide for a balanced ecosystem.
- Protecting and Restoring Vital Habitats - The Bay Program aims to preserve, protect and restore those habitats and natural areas that are vital to the survival and diversity of the living resources of the Bay and its rivers.
- Improving Water Quality - Improving water quality in the Bay and its rivers is the most critical element in ensuring the future health of Chesapeake Bay.
- Managing Lands Soundly - Because pollutants on land are easily washed into streams and rivers, our actions on land ultimately affect the Bay.
- Engaging Individuals and Local Communities - To contribute to Bay restoration, we have to first be concerned about resource stewardship in our own communities, homes and backyards.

RELEVANT CBNERRVA GOALS, OBJECTIVES AND STRATEGIES

CBNERRVA strives to achieve NERRS and VIMS research oriented goals by implementing a variety of strategies in support of CBNERRVA programmatic goals and objectives listed below. (Reay *et al*., 2008)

Goal 1. Enhance scientific understanding of coastal ecosystems, surrounding environments and the natural and human processes influencing such systems.

Objective 1. Characterize and monitor coastal ecosystems and surrounding environments to describe reference conditions and quantify spatial and temporal changes.

Strategies:

- Maintain and enhance long-term water quality monitoring in the York River and other appropriate water bodies to allow criteria and standards development, and overall water quality condition assessments.
- Maintain and enhance long-term meteorological and atmospheric monitoring within the southern Chesapeake Bay watershed to quantify key (e.g., nitrogen and mercury) contaminant loadings.
- Support biological monitoring of critical habitats (e.g., emergent wetlands, submerged aquatic vegetation) and the development of sentinel sites to address ecosystem responses to climate- and human-induced stress.

Objective 2. Determine linkages within and between coastal ecosystems and how linkages affect those systems.

Strategies:

- Determine how circulation patterns, mixing processes and exchange of water between regions (e.g., shoal, channel) of the York River system, its watershed and the Chesapeake Bay proper affect water quality, primary productivity and biological communities (e.g., benthic, nekton, plankton).
- Determine watershed (e.g., groundwater, stormwater runoff), airshed and Bay/oceanic material flux into the York River system.
- Examine how upland, shoreline and water management changes affect material flux and coastal ecosystems.
- Examine how episodic events (e.g., inter-annual variations in hydrologic budgets, large-scale storm events) and longer-term climatic changes affect material flux and coastal ecosystems.
- Examine rates and patterns of sea-level rise, subsidence and shoreline erosion and ecosystem responses to these processes within the York River system.
- Examine the relationship between environmental factors and the structure and function of coastal ecosystems (e.g., impacts of water clarity and temperature on seagrass beds; impacts of salinity and water level on wetland plant communities).

Objective 3. Promote, coordinate, track and support research and monitoring activities within Reserve boundaries and the York River system.

Strategies:

- Establish and maintain contact, and where appropriate, coordinate activities among groups with estuarine research interests.
- Identify research priority focus areas and encourage their investigation within Reserve components and the broader York River and Chesapeake Bay system.
- Utilize a permit system to approve and track research and related activities within Reserve boundaries.
- Continue to implement the NOAA/NERRS Graduate Research Fellowship program.
- Reserve associated faculty will continue to advise and mentor undergraduate and graduate students through participation in intern programs (e.g., NSF/VIMS Research Experience for Undergraduates, National Aquarium in Baltimore Conservation Intern Program) and through student advisory committee service.
- Seek external funding to advance research and monitoring activities.

Goal 2. Promote the effective management and conservation of natural and cultural coastal resources through informed decision-making.

Objective 1. Communicate results of research, environmental monitoring and best available science-based information to assist in improved coastal resource management.

Strategies:

- Serve in an advisory capacity to national, regional, state and local coastal resource management, research and education agencies, organizations and interest groups
- Provide the best available science-based information and skill building opportunities, with respect to priority needs, to coastal resource decision-makers and other appropriate audiences via a variety of formats including training workshops, sponsored conferences and developed information products.
- Develop, maintain and/or link to web-based data and information portals to manage and disseminate Reserve associated science and education information products, environmental databases, and associated metadata.
- Support the development and implementation of Bay-wide and specific tributary strategies and contaminant reduction plans in support of protection and restoration of water quality and habitats of concern.
- Participate in local (Virginia Estuarine and Coastal Observation System), subregional (Chesapeake Bay Observing System) and regional (Mid-Atlantic Coastal Ocean Observing Regional Association) Integrated Coastal and Ocean Observing System (ICOOS).

NERRS GRADUATE RESEARCH FELLOWSHIP PROGRAM

The Graduate Research Fellowship Program (GRF) supports students to produce high quality research in the reserves (Figure 1). The fellowship provides graduate students with funding for 1-3 years to conduct their research, as well as an opportunity to assist with the research and monitoring program at a reserve. Funds are available on a competitive basis and no more than two fellowships per designated reserve are allowed at any one time. Fellowships typically start on June 1 of each year. Awards may be used for salary, to defray the costs

Figure 1. NOAA/NERRS Graduate Fellow, conducting field studies at Goodwin Island. Photo credit: Kenneth Moore.

of living expenses, tuition, fees and/or research supplies. Students admitted to or enrolled in a full-time Masters or Doctoral program at U.S. accredited colleges and universities are eligible to apply. Students should have completed a majority of their course work at the beginning of their fellowship, and have an approved thesis research program.

Projects must address coastal management issues identified as having regional or national significance, relate to the reserve system research focus areas and be conducted at least partially within one or more designated reserve sites. Proposals must focus on one or more of the following areas: (1) eutrophication, effects of non-point source pollution and/or nutrient dynamics; (2) habitat conservation and/or restoration; (3) biodiversity and/or the effects of invasive species; (4) mechanisms for sustaining resources within estuarine ecosystems; and/or (5) economic, sociological, and/or anthropological research applicable to estuarine ecosystem management. Students work with the research coordinator or manager at the host reserve to develop a plan to participate in the reserve's research and/or monitoring program. Students are asked to provide up to 15 hours per week of research and/or monitoring assistance to the reserve; this training may take place throughout the school year or may be concentrated during a specific season.

NATIONAL MONITORING PROGRAM

It is the policy of CBNERRVA to implement each phase of the System-Wide Monitoring Plan initiated by NOAA's Estuarine Reserves Division (ERD) in 1989, and as outlined in the System-Wide Monitoring Program (SWMP) (NERR, 2007).

Phase I. Abiotic monitoring including water quality and meterological monitoring;

Phase II. Biological monitoring including submerged aquatic and emergent vegetation monitoring; and

Phase III. Landuse and habitat change including Reserve habitat and watershed land use mapping.

The SWMP provides standardized data on national estuarine environmental trends while allowing the flexibility to assess coastal management issues of regional or local concern. The principal mission of the monitoring program is to develop quantitative measurements of short-term variability and long-term changes in the integrity and biodiversity of representative estuarine ecosystems and coastal watersheds for the purposes of contributing to effective coastal zone management. The program is designed to enhance the value and vision of the reserves as a system of national reference sites. The program also takes a phased approach and focuses on three different ecosystem characteristics. These are:

- Abiotic Variables: The monitoring program currently measures temperature, specific conductance, dissolved oxygen, turbidity, pH, water level and atmospheric conditions (Figure 2). In addition, the program collects monthly nutrient and chlorophyll a samples and monthly diel samples at one SWMP data logger station. Each reserve uses a set of automated instruments and weather stations to collect these data for submission to a centralized data management office.
- Biotic Variables: The reserve system is focusing on monitoring biodiversity, habitat and population characteristics by monitoring organisms and habitats as funds are available.
- Watershed and Landuse Classifications: This component attempts to identify changes in coastal ecological conditions with the goal of tracking and evaluating changes in coastal habitats and watershed land use/cover. The main objective of this element is to examine the links between watershed land use activities and coastal habitat quality.

These data are compiled electronically at a central data management "hub," the Centralized Data Management Office (CDMO) at the Belle W. Baruch Institute for Marine Biology and Coastal Research of the University of South Carolina. They provide additional quality control for data and metadata and they compile and disseminate the data and summary statistics via the Web (http://cdmo.baruch.sc.edu) where researchers, coastal managers and educators readily access the information. The metadata meets the standards of the Federal Geographical Data Committee.

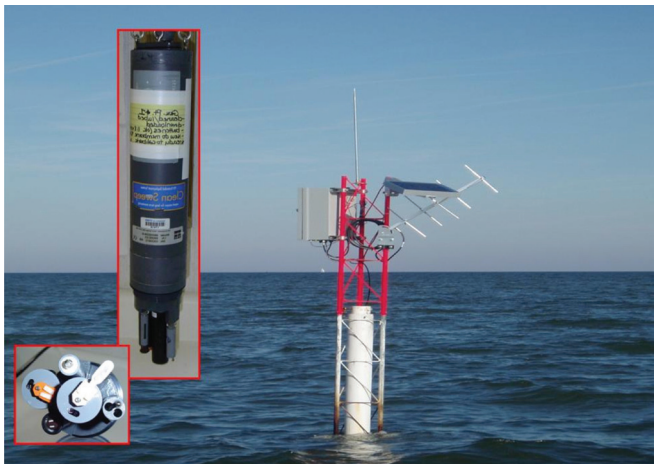

Figure 2. Goodwin Island SWMP continuous water quality monitoring station equipped with GOES satellite transmitter. Insert: YSI EDS water quality datalogger. Photo credit: William Reay.

ONGOING YORK RIVER MONITORING PROGRAMS

Meteorological and Streamflow Monitoring

- **CBNERRVA System-Wide Monitoring Program (SWMP).** CBNERRVA staff maintains meteorological monitoring stations at the Sweet Hall Marsh (established September 1998), Taskinas Creek (August 1997) and Goodwin Islands (January 2006) components of the Reserve. (Figure 3) Measured parameters include air temperature, relative humidity, precipitation, photosynthetic active radiation (PAR), barometric pressure, wind speed and direction. Real-time delivery of this data is currently available at selected stations. Selected data are available via the web at http://cdmo.baruch.sc.edu.

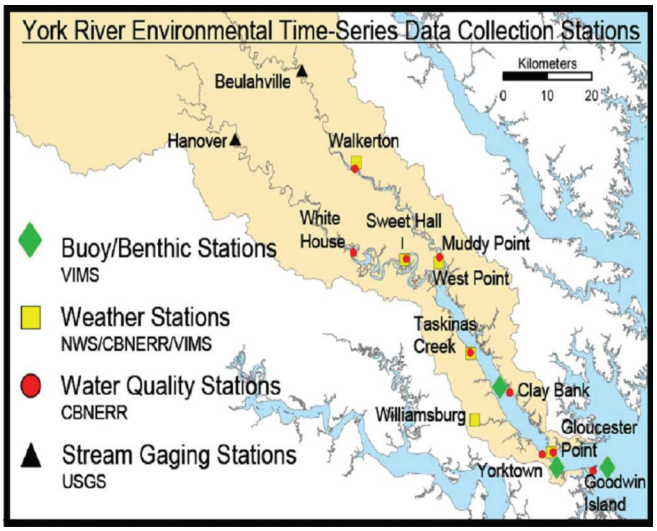

Figure 3. York River system continuous environmental data collection stations.

- **VIMS Meteorological Monitoring Program.** VIMS staff maintain a meteorological station at the Gloucester Point campus (May 1986) that is located approximately nine kilometers from Goodwin Islands. Measured parameters include air temperature, precipitation, PAR, and wind speed and direction. Selected data are available via the web at http:www.vims.edu/resources/databases.hrml.

- **National Streamflow Information Program.** The US Geological Survey (USGS) operates and maintains stream gages within the York River basin in order to provide long-term information on streamflow. Key stream gages above tidal influence on the Mattaponi and Pamunkey Rivers include the stations at Beulahville (USGS ID: 01674500; data available from 9/19/1941 to present) and Hanover (USGS ID: 0167300; data available from 10/1/1941). Selected data are available via the web at: http://www.water.usgs.gov/nsip.

- **National Atmospheric Deposition Program's National Trends Network (NADP/NTN) and Mercury Deposition Network (NADP/MDN).** CBNERRVA staff maintains the southern Chesapeake Bay NADP/NTN and NADP/MDN station (ID: VA98) located at Harcum, Va. The purpose of the network is to collect data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends of concentrations and loading rates. Measured physical parameters include air temperature, precipitation, PAR, wind speed and direction. Measured chemical parameters include hydrogen ion activity (acidity as pH), sulfate, nitrate, ammonium, chloride, base cations (such as calcium, magnesium, potassium and sodium), total mercury and methyl-mercury. The NADP/NTN and NADP/MDN stations were established in August, 2004 and December, 2004, respectively. Realtime delivery of physical parameters is currently available at this station. Selected data are available via the web at http://nadp.sws.uiuc.edu.

Water Quality Monitoring

- **CBNERRVA System-Wide Water Quality Monitoring Program (SWMP).** CBNERRVA staff maintain fixed continuous water quality stations at the Goodwin Island (established October 1997), Taskinas Creek (September 1995), and Sweet Hall Marsh (January 1999) components of the Reserve and at Gloucester Point (March 2003), Clay Bank (January 2002) and White House (Marsh 2003) within the York River estuary system (Figure 3). Multi-parameter water quality monitors (model: YSI 6600 EDS) measured water temperature, specific conductance, dissolved oxygen, pH, turbidity, fluorescence and water depth at 15-minute intervals. In addition, the program collects monthly nutrient (nitrate, nitrite, ammonium, phosphate) and chlorophyll a samples at all primary SWMP stations and monthly diel samples at one SWMP station. Realtime delivery of this data is currently for selected stations via the NWS Hydrometeorological Automated System (HADS) webpage (http://www.nws.noaa.gov/oh/hads) and selected archived data is available via the web at the NERRS CDMO (http://www.cdmo.baruch.sc.edu) and VECOS http://www2.vims.edu/vecos).

- **VIMS Virginia Nearshore Water Quality Monitoring Program.** CBNERRVA and VIMS staff monitor nearshore surface water quality along a transect in the lower York River estuary. Measured parameters include air and water temperature, salinity, inorganic nitrogen and phosphorus, chlorophyll a, total suspended solids, PAR, light extinction coefficient, and color. Water quality samples have been collected bi-weekly since 1984.

- **Chesapeake Bay Program (USEPA and VaDEQ) York River Water Quality Monitoring Program.** Multi-depth samples are collected along a main channel transect in the York, Mattaponi and Pamunkey Rivers to support the multi-agency Chesapeake Bay Program. Station ID's: York River proper, the Pamunkey River and Mattaponi River. Measured parameters include water temperature, specific conductance, dissolved oxygen, pH, Secchi depth, chlorophyll a, pheaopigments, total suspended solids, dissolved inorganic and total nitrogen, total particulate nitrogen, dissolved inorganic and total phosphorus, particulate phosphorus, dissolved and particulate organic carbon. Water qual-

ity samples have been bi-weekly/monthly since 1984. Selected data are available via the web at http://www.chesapeakebay.net/data/index.htm.

- **Chesapeake Bay Program (U.S.EPA, NOAA, and VaDEQ) Enhanced Shallow Water Quality Monitoring Program.** CBNERRVA staff maintains additional fixed continuous (15 minute interval) water quality stations and conducts high frequency spatial water quality monitoring and mapping (using Dataflow) in a number of southern Chesapeake Bay tributaries. With respect to Dataflow, water quality and GPS location measurements are typically taken at 50-100 m intervals along the vessel track in both shallow (<1.5m) and channel areas. Fixed continuous stations and the Dataflow system utilize multi-parameter water quality monitors (model: YSI 6600 EDS) and measure water temperature, specific conductance, dissolved oxygen, pH, turbidity, chlorophyll fluorescence and water depth. Temporal sampling has typically been linked to SAV growing seasons (high salinity: March-November; low salinity: April-September) but recently has expanded to include late winter/spring to capture migratory fish spawning and nursery use in tidal freshwater and low salinity waters. In addition to York River efforts, continuous fixed water quality stations and Dataflow mapping activities occur within the James (2006-current), Rappahannock (2007-current) and portions of the Potomac (2007-current; fixed stations only). Selected data are available via the web at http://2/vims.edu/vecos.

  Note: In addition to Biological information, selected water quality and weather information is available for the cited biological monitoring programs below.

Biological Monitoring

- **VIMS Juvenile Fish and Blue Crab Trawl Survey** (Figure 4). Initiated in 1968, the primary goal of this survey is to develop indices of abundance, which measure the relative size of each year class of a target species. These indices indicate annual recruitment success or failure and help predict the future abundance of the stock. Fish and selected invertebrates (e.g., blue and horseshoe crab, squid) are collected monthly (except January and March) at stratified stations and historical fixed mid-channel stations within the York River estuary including the Mattaponi and Pamunkey River systems by the Institute's Fisheries Science Department. Selected data are available via the web at www.fisheries.vims.edu/research.html.

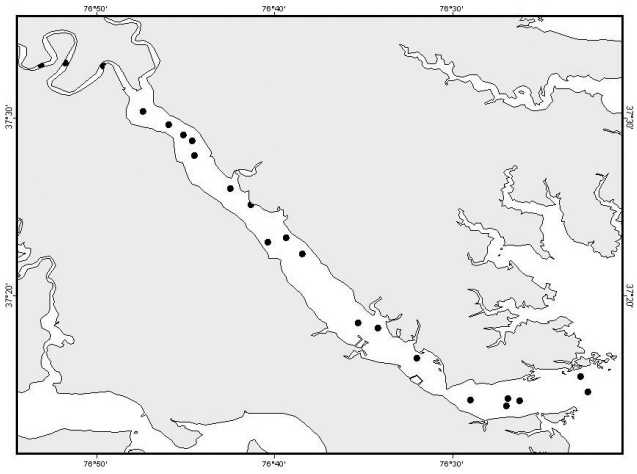

Figure 4. York River VIMS trawl survey stations. May 2005.

- **VIMS Juvenile Striped Bass Seine Survey.** Initiated in 1967-1973 and reinstated in 1980, the primary objective of this survey is to monitor the relative annual recruitment success of juvenile striped bass in the spawning and nursery areas of lower Chesapeake Bay. Fish and selected water quality information are collected on approximately five biweekly sampling periods from July through mid-September at primary index and auxiliary stations within the York River estuary including the Mattaponi and Pamunkey River systems by the Institute's Fisheries Science Department. Selected data are available via the web at www.fisheries.vims.edu/research.html.
- **CBNERRVA System-Wide Biological Monitoring Program (SWMP).** CBNERRVA staff participate in field monitoring of submerged aquatic vegetation and emergent wetlands within Reserve boundaries. Initiated in 2004, fixed transects located within SAV beds at Goodwin Islands and Gloucester Point are monitored in order to quantify SAV inter-annual variability in shoot density and distribution and identify any relationship to water quality (Figure 5). SAV transect monitoring occurs on a monthly basis, typically from April through October. Fixed transects within emergent wetland vegetation have been established at each of the Reserve components in order to measure plant diversity over time and a function of salinity regime. Monitoring of emergent wetland transects occurs during the summer on an approximately five year basis. CBNERRSVA is working in partnership with the NOAA Restoration Center in monitoring wetlands in the Sweet Hall Marsh Reserve Site to serve as a reference site for comparison with wetland restoration projects throughout the mid-Atlantic region.
- **Virginia Department of Health.** The VaDOH/Division of Shellfish Sanitation conducts the Shoreline Survey


Figure 5. Sampling along long-term fixed SAV biomonitoring transect. Photo credit: Kenneth Moore

and Seawater Sampling Programs along a series of sites in the York River estuary (which includes lower portions of the Mattaponi and Pamunkey River systems) in order to assess suitability classification of shellfish waters. The Seawater Sampling Program analyzes for fecal coliform bacteria at approximately monthly intervals while the Shoreline Survey inspects all properties within a drainage basin that are deemed capable of impacting shellfish waters at approximately 6-8 year intervals. Information regarding these programs is available via the web at www.vdh.state.va.us/environmentalhealth/shellfish.

- **VIMS Chesapeake Bay Submerged Aquatic Vegetation (SAV) Survey.** Initiated in 1971, SAV distribution, community types and density classes are mapped from aerial photography, primarily at a scale of 1:24,000. Bay-wide information is available for 1978, 1984 - 1987, and 1989 – 2007. Virginia western shore, lower and upper regions are available for 1971 and 1974, 1980-1981 and 1979, respectively. Data are stored in ArcInfo GIS coverages and information is available from the Institute's Biological Sciences Department at http://www.vims.edu/bio/sav.

RESEARCH POLICIES AND PROCEDURES

Research opportunities at Reserve sites are available to any qualified scientist, academician or student affiliated with a university, college or school, any non-profit organization, non-academic research institution (e.g., research laboratory, independent museum, and professional society), any private profit organization, and any state, local or federal government agency. Research opportunities will also be available to unaffiliated individuals who have the capability, facilities, and resources needed to perform the work. All researchers must complete and submit a CBNERRVA research application permit for work to be conducted within the Reserve system. In addition, research activities within the Taskinas Creek component of the Reserve require approval from the Virginia Department of Conservation and Recreation (VaDCR).

Research opportunities are available to all applicants without regard to manner of funding. Financial support for research may come from international, federal, state, local government, non-profit organizations, and from private individual sources. Examples of international sources include the United Nation's Man and the Biosphere, Food and Agriculture Organization and the Educational, Scientific and Cultural Organization programs. Federal sources may include USEPA, NOAA, National Marine Fisheries Service, National Sea Grant Program, the National Science Foundation, U.S. Department of Agriculture, and the U.S. Department of the Interior. Funding from state sources include the Virginia General Assembly and state resource management agencies, and localities. Non-profit organizations or foundation financial sources include the Virginia Environmental Endowment, The Nature Conservancy, Chesapeake Bay Foundation and the Alliance for the Chesapeake Bay.

RESERVE MONITORING AND RESEARCH NEEDS AND PRIORITIES

Because of proximity of graduate research institutions such as the Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, and other universities such as Old Dominion University, Hampton University and the Virginia Commonwealth University, a great deal of research and monitoring is ongoing within the York system, in general, and the reserve sites, in particular. Of highest priority are those studies that further the Goals and Objectives of CBNERRVA to characterize and monitor the local ecosystems, to quantify spatial and temporal changes, to determine linkages within and between these systems and to determine how these linkages affect those systems.

The manifestations of global climate change and sea level rise on the local reserve system are of high priority for reserve research and monitoring activities. The impacts of these long-term factors have already been observed within York system; however, much more information is needed relative to their effects especially on the individual reserve sites. Some important topics include: effects on sediment transport, erosion and deposition; rates and impacts of salinity intrusion as well as freshwater inputs from storms on physical-chemical processes and biota including fish, benthos, wetlands and submerged aquatic vegetation; temperature impacts, especially those related to short-term extremes; rates and effects of euthrophication including atmospheric, non-point source, and ground water inputs; effects on hypoxia; impacts on habitat composition, diversity, function, recruitment and community succession.

Euthrophication mechanisms and effects especially that are related to landscape change and human development are another priority. The York River watershed is relatively undeveloped compared to other systems in the Chesapeake Bay; however the trend of increasing growth is unending. The fate and effect of elevated nutrient and sediment loads on the system are still not well understood. Much more work is needed on the interrelationships of euthrophication and the physics of the system. For example, the development of harmful algal blooms can be related to both the input of nutrients and the residence time in the system. Both nutrients and sediments affect SAV development and restoration, yet they interact with each other and with physical factors and sedimentalogical conditions.

Another priority area for research and monitoring includes the inputs, fates and effects of contaminates within the system. Atmospheric inputs of contaminants such as mercury are not well understood. The distribution, abundance, and impact of chlorinated hydrocarbons are thought to be widespread and significant, yet much is still unknown. The bioaccumulations and effects of contaminants including heavy metals, pesticides on the marine food web including the zooplankton are not well understood or studied. The York River is the site of a large oil refinery and paper mill but their effects are poorly studied. Human health issues have not been significant in the York system however there has been an increase in harmful algal blooms and increased potential for bacterial contamination from both human and animal sources. The quantification and tracking of viral and bacterial organisms affecting both humans and other organisms in the system are important topics for future work.

Invasive species have already had pronounced effects on the system. More work is needed on the quantification and identification of invasive species and their control. Although the distribution and abundance of many plant and animal components of the have been well studied, more work needs to be done on the benthos, zooplankton and algae.

Finally, more research and longer term monitoring is required relative to community and system restoration. There are large gaps in the knowledge of the relative efficacy of restoration activities; their cost, effectiveness and optimization of techniques. The role of founder species, diversity and succession in plant community restoration are not well known. Only recently have reference sites for freshwater wetland and seagrass communities been developed, from which restoration sites can be compared. The vegetation reference monitoring sites need to be expanded to include other communities along the entire system.

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