STAR REPORT

U.S. EPA Office of Research and Development's Science To Achieve Results (STAR) Research in Progress

Vol. 3 Issue 1 July 1999 A product of the National Center for Environmental Research and Quality Assurance

ECOLOGICAL EFFECTS OF COASTAL STRESSORS

1998 was designated the "Year of the Ocean" through the efforts of a host of national and international ocean education and conservation organizations and public agencies. In a 1997 study relevant to technical information needs for U.S. coastal assessments, a team of federal scientists and program managers convened by the Federal Interagency Committee on Environment and Natural Resources had released the report, "Integrating the Nation's Environmental Monitoring and Research Networks and Programs: A Proposed Framework." They recommended creating a network of index sites that could provide standardized information on coastal ecological condition, filling a critical gap in the nation's ability to assess the health of ecosystems.

Responding to this recommendation, in 1998 the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA) established CISNet (the Coastal Intensive Site Network). This program will develop a network of coastal monitoring and research locations. Within EPA, CISNet is a component of the Environmental Monitoring and Assessment Program, which conducts research into monitoring design and implementation to address a range of ecological resources, including coastal ecosystems. Within NOAA, CISNet research is jointly supported by programs including the National Sea Grant College, the National Estuarine Research Reserve System, and other components of the National Ocean Service. Within NASA, CISNet research is a component of the "Mission to Planet Earth", and aims at developing remote sensing capabilities to complement the EPA and NOAA field work. In many cases CISNet sites are existing federal or academic research stations.

CISNet supports baseline monitoring of ecological condition simultaneously with use of the sites as "outdoor laboratories" for fundamental research to better understand ecosystem processes and responses to stress. Results eventually will include better descriptions and understanding of short-term

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coastal variability, monitoring of long-term trends, and determining which indicators are most useful for identifying stress and responses to stress in coastal systems across the range of conditions found in U.S. coastal regions.

Following is a description of current STAR CISNet projects. If not otherwise described, these projects are supported by EPA funds. Where some or all funds are from other federal agencies, that is noted.

Atlantic and Gulf Coast CISNet Studies

The University of North Carolina at Chapel Hill is building on an existing twenty-year data base recording water quality and ecological conditions of the Neuse River Estuary. Researchers will expand on the previous research to evaluate the mechanisms of nitrogen-driven eutrophication. The Neuse is experiencing nuisance algal blooms, low oxygen and fish kills. In 1997 it was listed by the American Rivers Foundation as one of the nation's most polluted rivers. It is presumed that increased nitrogen loads from human population growth and various land use changes contribute to the observed impacts, but there is not a complete understanding of the importance of various stressors, or of the ways in which the ecosystem is responding. Nevertheless, in 1997 the state of North Carolina was driven by public pressure to take protective measures, and legislation was passed directing that reductions in nitrogen loading be achieved, and that a "nutrient response model" be developed as a tool for managing future nutrient loading. A target of 30 percent nitrogen reduction from point and nonpoint sources over the next 5 years is being sought. Monitoring and process studies over this time period should provide an exceptionally useful setting for observing ecosystem response to decreased nutrient loads. The researchers are assessing nutrient inputs from airborne and waterborne pollution, with sources including urban and suburban runoff and air emissions, row crops and livestock. They are assessing ecological quality through plankton and water quality analysis. Detailed hydrographic monitoring and modeling are used to assess pollutant transport routes. Results should be directly relevant to the needs to verify and evaluate the state's overall nutrient response model, supporting any needed modifications for its continued use for water quality management in the future.

Investigators from the **Smithsonian Environmental Research Center** are studying the Rhode River, a Chesapeake Bay tributary and an established CISNet Site, assessing how well certain aquatic optical properties serve as indicators of responses to natural and anthropogenic stressors. Although stresses affecting coastal systems vary from site to site, and there is wide natural variability in ecological characteristics, stressors common to most coastal waters result in characteristic changes in spectral attenuation of light underwater. The spectrum of light penetration

is influenced by suspended particulate matter, phytoplankton chlorophyll and colored dissolved organic matter. These parameters serve as indicators to integrate each system's response to a combination of stressors. This study will develop the capability to continuously and cost-effectively monitor the parameters as they respond to perturbations on varying time scales. These will range from individual storms or phytoplankton blooms to the seasonal, decadal or even longer responses relevant to some natural ecosystem changes and to changes in land use and other human impacts, including environmental management programs. In a related study, the **University of Maryland Center for Environmental Science** is conducting remote sensing analyses and field work needed to establish the Choptank River, a second tributary of the Chesapeake Bay, as a new CISNet Site. EPA and NASA are jointly funding this work, which combines analyses of aerial and satellite imagery with data from automated buoys designed to continuously monitor water chemistry and associated data with high spatial and temporal resolution. The study overall focuses on impacts of weather fluctuations and nutrient inflows. Specific objectives are to: 1) assess the role of marshes and submerged aquatic vegetation in modulating nutrient fluxes from land to water; 2) quantify the effects of changing nutrient loads on water quality and living resources in this system; 3) document effects of specific nutrient management actions on nutrient loads; and (4) evaluate indicators of condition and ecological sustainability over a range of ecological states.

A set of indicators ranging from molecular to landscape scales are being simultaneoulsy tested to monitor estuarine eutrophication at the the North Inlet-Winyah Bay National Estuarine Research Reserve CISNet Site in South Carolina. The **University of South Carolina** is continuing and enhancing that Site's long-term monitoring program to address basic and applied questions about eutrophication impacts. Ongoing data collection will be linked with new measurements of phytoplankton and bacterial community structure made possible by advances in molecular biology and analytic chemistry. The biotic change indicators have broad application and rely on technologies that could be widely adopted. The community structure data will be compared to indices of wetland productivity and change based on landscape-scale remote-sensing (satellite) data. The North Inlet and Winyah Bay are in close proximity but have extreme differences in nutrient loading, nutrient dynamics and productivity, making them ideal natural laboratories for assessing these indicator methodologies in a range of conditions. The goal is to improve the value of the current monitoring program by adding practical new parameters that demonstrate linkages between water quality factors and nutrient

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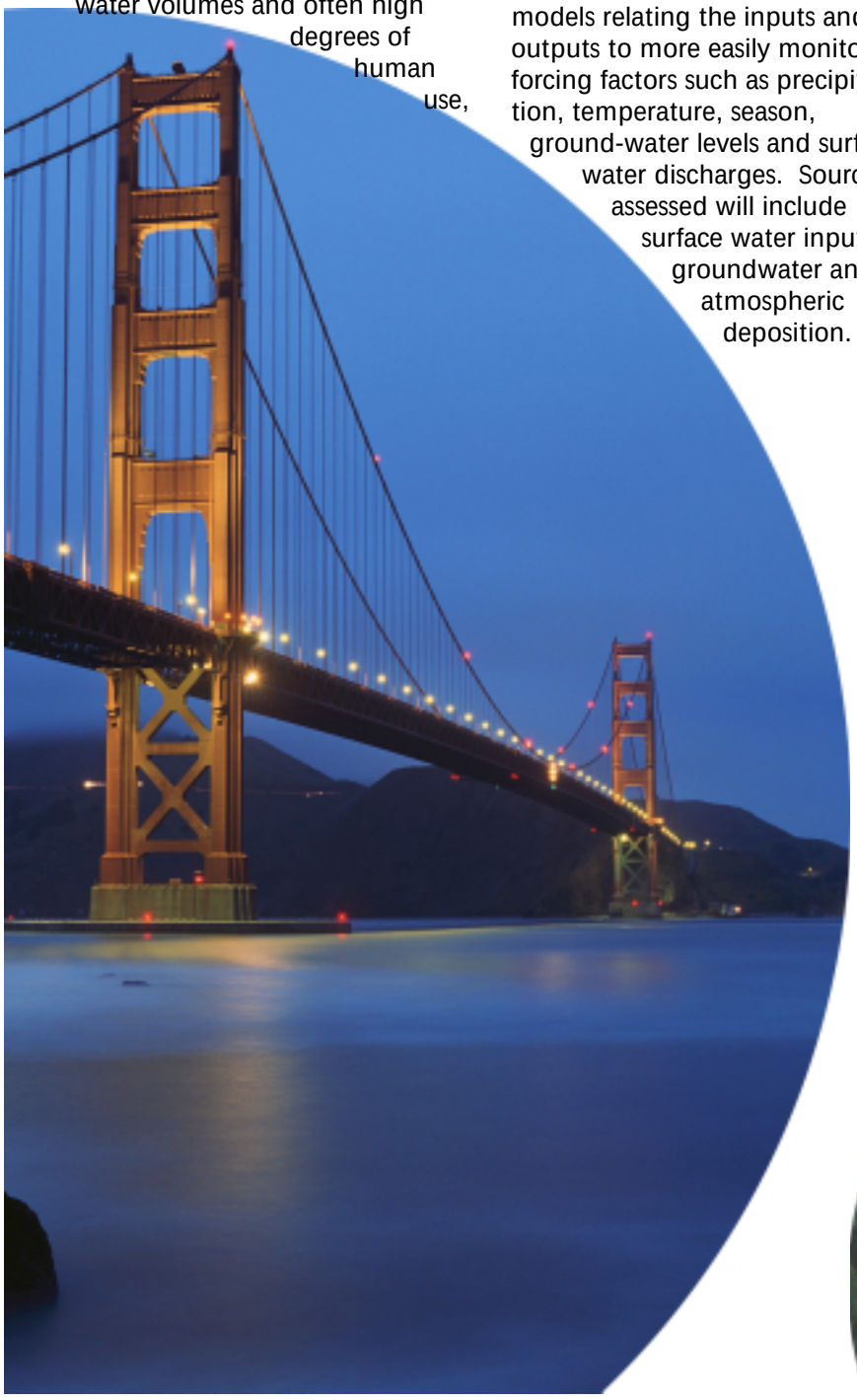
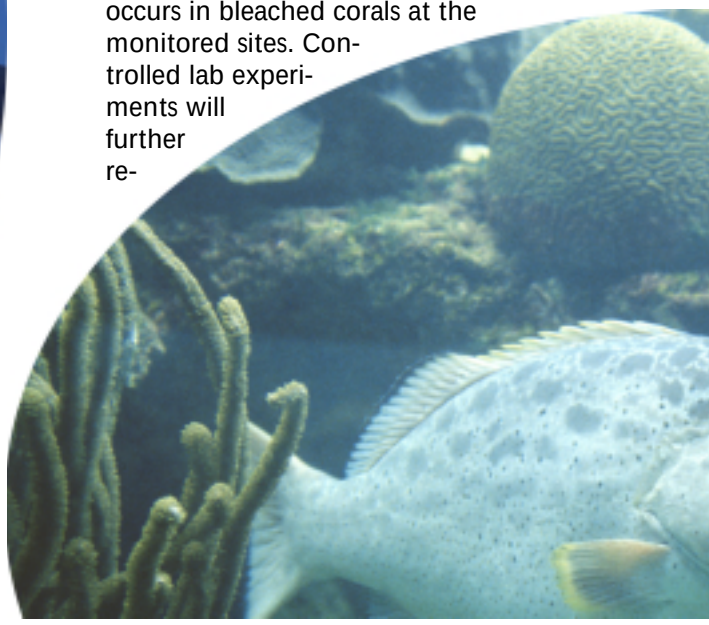
uptake, feeding and survival of various types of bacteria and plankton.

Delaware's "Inland Bays" ecosystem, including Rehoboth and Indian River Bays, is an example of the small, often very shallow waters between barrier islands and the mainland that characterize much of the U.S. Atlantic and Gulf Coasts. Such small systems are relatively unstudied. They are typically subject to serious pollution stress because of their low water volumes and often high degrees of human use, often including seasonal tourism combined with crops, poultry farming or other livestock. The **University of Delaware** is studying nutrient inputs and net nutrient fluxes out of the Inland Bays as an indicator of stress response. They will evaluate nitrogen and phosphorus dynamics to determine the primary stressors in the system, their sources and the magnitudes of nutrient sinks, including Bay sediments; They will also develop conceptual and quantitative models relating the inputs and outputs to more easily monitored forcing factors such as precipitation, temperature, season, ground-water levels and surface-water discharges. Sources assessed will include surface water inputs, groundwater and atmospheric deposition. Models developed will be directly relevant to state needs to plan for wastewater management needs and pollution control measures in these areas as human uses increase in the future.



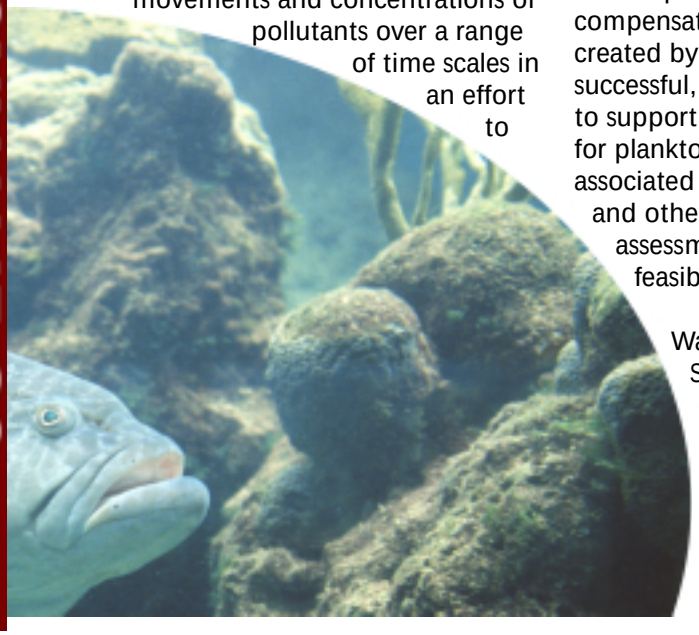
In the Florida Keys National Marine Sanctuary, scientists from the **University of California at Davis' Bodega Marine Laboratory** are conducting a CISNet research project evaluating the role of climate change in altering penetrance of ultraviolet (UV) radiation over coral reefs, potentially contributing to coral bleaching. The study involves coordinating with EPA scientists who specialize in coral disease identification and the measurement of underwater UV radiation. It will incorporate data from on-going Sanctuary programs to characterize temperature and overall light conditions. Climate change may contribute to coral bleaching because thermal stratification (ocean water layering) can lead to sea surface warming and increased UV penetration, both associated with bleaching. Remote sensing will be used to assess underwater UV levels under stratified and unstratified conditions. Coral genetics studies will investigate a type of DNA damage, the presence of thymine dimers, known to be specific to UV irradiation, assessing whether the damage occurs in bleached corals at the monitored sites. Controlled lab experiments will further re-



fine the use of this DNA "biomarker" as a potential indicator of coral ecosystem health.

West Coast Studies

San Pablo Bay is the northern sub-embayment of the San Francisco Bay. Its largest freshwater inflows are the combined Sacramento and San Joaquin Rivers, which drain the massive agricultural Central Valley of California. The freshwater flow is moderated by tidal ocean inflow . This fairly small bay receives an exceptionally large pollutant load, including sediment loads and pesticide residues from the Central Valley together with discharges from a heavy local concentration of refineries and other industrial facilities. Dredging and wetland restoration projects are further influencing the ecosystem, with the restoration projects offering the potential for improving the Bay's health if their design proves successful. Two grants, one from EPA and one from NASA, have been awarded to develop assessments techniques for the Bay. Under the EPA grant, the **University of California at Davis** is designing a monitoring network to provide advance warning and long-term tracking of the impacts of natural changes and human impacts. They will document movements and concentrations of pollutants over a range of time scales in an effort to design optimization techniques for selecting monitoring locations and temporal frequencies at this and other CISNet Sites. Indicators will be chosen by testing an extensive set of chemical, biochemical and ecological variables to select a suite of measures that are both ecologically most meaningful and cost effective for long-term use. Results are expected to include an improved understanding of the relationships among sediment bound contaminants and impacts on the food chain, including fish and birds. The work will support decisions concerning pollution reduction strategies and provide information for evaluating dredging and wetlands restoration projects.



Through the NASA grant, the **California State University at San Francisco** is using Advanced Very High Resolution Radiometry (AVHRR) and Sea Wide Field Sensor (SeaWiFS) satellite imagery to produce images of surface temperature, pigment concentrations and sediment loads for San Pablo Bay and other portions of San Francisco Bay, and to attempt to produce new kinds of high temporal resolution data on plankton productivity. The use of these techniques for waters very close to shorelines is a new technique, requiring development of site-specific algorithms and compensation for distortions created by proximity to land. If successful, this approach promises to support use of satellite imagery for plankton productivity and associated parameters at CISNet and other sites where such assessments are not presently feasible.

Washington State's Puget Sound is a different kind of estuary than San Pablo Bay or the Atlantic Coast estuaries. Like others, the Sound is a water body where river inputs mix with tidal ocean inflow, but it differs in geological history, shape and hydrology. Many estuaries are river mouths submerged as sea level rose, creating elongated shallow bays. In contrast, central Puget Sound is a deep fjord created by faults and tetonic activity, bordered by a network of narrows. The topography results in complex flows that vary with river input, tides and wind. Population growth has led to nutrient enrichment problems, especially in the narrows. To monitor the transport regime and water quality requires hydrologic, chemical and biological sampling approaches tailored to this complex system.

The **University of Washington** has received two grants to address these issues for Puget Sound. The first, funded by EPA, involves *in situ* monitoring of primary productivity and nutrient cycles. To deal with the rapid flows, a special profiling instrument system that measures chemistry, chlorophyll and flows throughout the water column will be deployed using a moored buoy. The associated NASA-funded study involves monitoring "water leaving radiance", an indicator of water color and clarity, and comparing it with ground truth images to be collected by the Navy Earth Map Observer (NEMO) satellite to be launched in 2000. Current satellites do not provide good resolution of water color and clarity close to shorelines, so they have not been useful in studying estuaries or the nearshore ocean. NEMO instruments have been designed to reduce this problem. It is expected that combining NEMO data with *in situ* profiling will allow long-term variations in nutrient cycling, productivity and phytoplankton biomass to be more fully assessed. This will be coupled with an existing three-dimensional model of circulation in the Sound. The resulting model

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of ecosystem dynamics will provide better understanding of current eutrophication impacts and support predictions of impacts of any future increases in nutrient loads.

Great Lakes

The Great Lakes Wisconsin Aquatic Technology and Environmental Research (WATER) Institute of the **University of Wisconsin-Milwaukee** has received a grant to build on a 50-year nearshore water quality record for southwestern Lake Michigan. They will add sites in harbor,additional nearshore and open lake habitats. This area is a drinking water source and an important perch spawning area. The long-term data set offers a unique opportunity to assess the impacts of stresses that have greatly increased since the monitoring began, including atmospheric nutrient deposition, increases in ultraviolet radiation (UV-B), invasions by exotic species, and the early increases and subsequent decreases in water pollution discharges from municipal and industrial sources. Indicators will include a suite of conventional (non-toxic) water quality parameters and biological factors, together with some toxic metal analyses. There will also be site-specific studies of zebra mussel feeding, and special studies to establish zooplankton migration patterns. Results are expected to help develop innovative methods to target stressors most responsible for general and site-specific impacts

Tropical Pacific

An interdisciplinary team of **University of Hawaii** investigators is being jointly funded by NOAA and NASA to study the linkages between sources of stressors in the watershed, and their impacts on the reef ecosystem. Historically,stresses were dominated by urbanization, including sewage discharge. In 1978, construction of a sewage outfall discharging offshore allowed considerable recovery of the Bay, including reef health and function. However, recent data suggest there has been only an incomplete return of the Bay to its pre-sewage state. This study will assess whether full recovery is "stalled" due to present-day pollution sources in the watershed, or whether current conditions are simply one of several possible natural states the system could exhibit. Results will be relevant to environmental management options as local managers attempt to balance recreational and commercial needs with long-term health of the reefs and associated fish and wildlife. Indicators to be monitored include water chemistry, plankton,sediment and benthic biological conditions, supported through the NOAA grant, coordinated with assessments of coral health based on remote sensing imagery analyzed under the NASA grant. Researchers hope to identify the wavelengths or wave bands that can best be used with lower-cost multispectral imagery techniques to classify reef health. Comparing this information with aquatic monitoring data will support recommendations of a set of cost-effective *in situ* and remotely sensed indicators for use in state monitoring and the national CISNET program.

CISNet Workshop Proceedings

Investigators from each of these CISNet research projects participated in a progress review workshop on February 22 to 23, 1999 in Gulf Breeze, Florida. A report providing abstracts of each project's work as presented at that meeting is available on the World Wide Web at http://www.epa.gov/ncerqa. (At this date use the general link to "publications" to access this report. This internal link may change as the website expands in future months.) A limited number of bound copies of the report are presently available from EPA's Office of Research and Development at the mailing address listed below.

STAR Research Projects Described in this Report

Note: Only Lead investigators are named. Most projects include multiple investigators

CISNet for the Neuse River Estuary, NC: A Program for Evaluating Nitrogen Driven Eutrophication Associated with Changing Land Use in a Coastal Watershed, Richard A. Luettich, University of North Carolina Chapel Hill (EPA grant)

CISNet: Coral Bleaching, UV Effects, and Multiple Stressors in Florida Keys, Susan L. Anderson, Regents of the University of California (EPA grant)

CISNet San Pablo Bay Network of Environmental Stress Indicators S. Geoffrey Schladow, The Regents of the University of California (EPA grant)

CISNet: Nutrient Inputs as a Stressor and Net Nutrient Flux as an Indicator of Stress Response in Delaware's Inland Bays Ecosystem, William J. Ullman, University of Delaware (EPA grant)

Monitoring Ecosystem Condition and Stress in the San Pablo Bay, California Region, Raphael Kudela, San Francisco State University (NASA grant)

Environmental Monitoring of Coastal Waters of Southwestern Lake Michigan, Russell Cuhel, University of Wisconsin-Milwaukee (NOAA grant)

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CISNet Molecular to Landscape-Scale Monitoring of Estuarine Eutrophication, James T. Morris, University of South Carolina (EPA grant)

Rhode River CISNet: Estuarine Optical Properties as an Integrative Response to Natural and Anthropogenic Stressors, Charles L. Gallegos, Smithsonian Institution (EPA grant)

CISNet: In Situ and Remote Monitoring of Productivity and Nutrient Cycles in Puget Sound Steven R. Emerson, University of Washington (EPA grant)

In Situ and Remote Sensing of Phytoplankton Biomass, Mary Jane Perry, University of Washington (NASA grant)

CISNet: Linkages Between a Tropical Watershed and a Reef Ecosystem, Robert Kinzie III, University of Hawaii (NOAA grant)

Hyperspectral Remote Sensing the Kaneohe Bay Tropical Estuary, Marlin Atkinson, University of Hawaii (NASA grant)

The Choptank River: A Mid-Chesapeake Bay Index Site for Evaluating Ecosystem Responses to Nutrient Management, Thomas C. Malone, University of Maryland, Center for Environmental Science (EPA grant)

Remote Observations in the Choptank River Index Site, Lawrence W. Harding, University of Maryland Center for Environmental Science (NASA grant)

General Information: The Environmental Protection Agency's STAR Research Program

Grants described in this report are part of EPA's Science to Achieve Results (STAR) program, a major research initiative designed to improve the quality of scientific information available to support environmental decision making. The STAR program is managed by EPA's National Center for Environmental Research and Quality Assurance in the Office of Research and Development (ORD). The program funds approximately 200 new grants every year, with the typical grant lasting three years. Funding levels vary from $50,000 to over $500,000 per year, with FY 1999 funding level at about $95 million for grants to individual principal investigators or groups of investigators. Additional STAR funds are provided for a number of Research Centers specializing in scientific areas of particular concern to EPA, and for a fellowship program supporting graduate students conducting environmental research.

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