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Coastal Intensive Sites Network (CISNet): STAR Grants 2000 Progress Review

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NATIONAL CENTER FOR ENVIRONMENTAL RESEARCH

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Introduction

In Fiscal Year 1998, the U.S. Environmental Protection Agency (EPA), in partnership with the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA), funded a set of research grants to investigate monitoring approaches and ecological indicators for future use at U.S. coastal monitoring sites. It is hoped that the research findings will be useful in the design of intensive, long-term monitoring and research, particularly in estuarine and great lakes environments. A potential program to plan for such sites, the Coastal Intensive Sites Network (CISNet), would be one possible application of the research, as would the many regional and state coastal protection and monitoring programs currently underway throughout the country. As a follow-on and expansion of this 1998 research program, EPA and NASA will be funding an additional set of larger, longer term grants called the Estuarine and Great Lakes (EAGLE) projects, which will be selected and funded at the end of 2000. Abstracts of the particular research to be funded under the EAGLE grants will be available on the EPA Web Site in late 2000 or early 2001.

This volume, prepared in support of a program progress review meeting to be held in Narragansett, Rhode Island, contains abstracts describing progress to date on the CISNet grants that were funded by EPA through its Science to Achieve Results (STAR) research program. (STAR is EPA's principal program for providing extramural grants to support environmental research). Abstracts of additional 1998 CISNet projects funded by NOAA and NASA will be available in a future progress review volume, when all of the grants near completion.

CISNet has three general objectives:

(1) To develop a scientific basis for understanding ecological responses to anthropogenic stresses in coastal environments, including the interactions of exposure, environment/climate, and ecological factors, and the spatial and temporal nature of these interactions.

(2) To demonstrate the usefulness of intensively monitored sites for examining short-term variability and long-term trends in the relationships between natural and anthropogenic stressors and ecological responses.

(3) To evaluate indicators of change in coastal systems at particular intensively monitored sites.

If you have any questions regarding EPA's CISNet grants, you can contact the program manager, Kim Devonald, at 202-564-5178, or by e-mail at devonald.kim@epa.gov. (For information about the future EAGLE program, contact the program manager, Barbara Levinson, at 202-564-6911.)

Indicators of UV Exposure in Coral and Their Relevance to Global Climate Change and Coral Bleaching

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The frequency and severity of coral bleaching has increased dramatically over the last 2 decades, posing a serious threat to coral resources worldwide. Bleaching can destroy large areas of a reef with limited recovery or recruitment, and it may be induced by a variety of stressors. Increased temperature is implicated in most bleaching events, but a possible synergy between temperature and ultraviolet light has been proposed.

Under conditions of ocean warming, often associated with calm, stratified waters, photobleaching of UV-absorbing chromophoric dissolved organic matter (CDOM) is increased, and penetrance of both UV-B and UV-A is greatly enhanced. Indices of UV-specific effects in coral tissue are needed to test whether increases in UV, associated with global climate change, are harmful to coral. To address this challenge, UV-specific effects in coral have been evaluated, and factors that alter penetrance of UV radiation over coral reefs have been characterized.

An immunoblotting assay was developed to examine UV-specific lesions (thymine dimers) in coral and zooxanthellae DNA. Dose-dependent increases of thymine dimers were observed in purified coral (*Porites porites*) DNA exposed to UV-C in the laboratory and with intact *P. porites* in a Suntest solar simulator. However, with whole coral, effects were not strictly proportional at the lowest exposure times (see Figure 1). Next, the assay was used to determine whether thymine dimers are detected under realistic field conditions (Maryland Shoals, Florida Keys, July 1999). Thymine dimers in *P. porites* collected at 0830 hrs and at 1300 hrs differed significantly ($p=0.04$). A diurnal variation experiment was conducted in July 1999 at Eastern Sambo Reef (Florida Keys), and samples currently are being analyzed. Sampling was conducted at multiple timepoints to determine whether thymine dimers follow hypothesized diurnal cycles. Chlorophyll, tissue protein, zooxanthellae counts, and carotenoid pigments also will be analyzed.

Immunofluorescence techniques are now being developed that will help determine where dimers are localized within coral tissue and zooxanthellae. Results obtained to date indicate that UV-specific effects can be discerned under field conditions and related to exposure dose. Studies now underway will help determine whether these effects are linked to coral bleaching and to other indicators of stress in coral. UV measurements also were made as part of the experiments conducted during July 1999 at Eastern Sambo reef and nearby sites including profiling along transects from reef to shore.

These findings represent the first known attempt to evaluate UV-specific DNA damage in coral, and together with the dosimetry data, they represent an important first step in assessing the role that UV radiation may play in coral bleaching. The next steps will be to: (1) complete development of the thymine dimer assay, (2) complete work underway to localize dimers in coral and zooxanthellae, and (3) evaluate interactions between temperature and UV light.

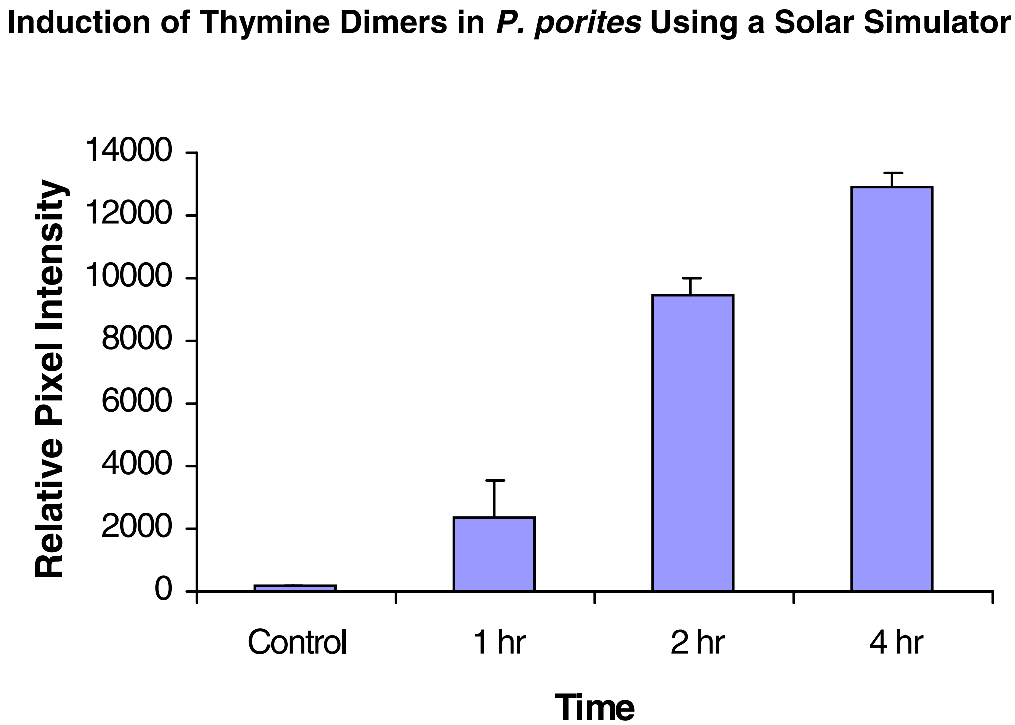

Figure 1. Coral pieces were collected from natural reefs in the Florida Keys and held in a UV-free environment prior to exposure in a solar simulator. Thymine dimers are represented as relative pixel intensity in 1.0 mg of DNA, and vary significantly in each treatment (Kruskal-Wallis P=0.01). Error bars represent standard deviation.

Factors Controlling UV Exposure of Coral Assemblages in the Florida Keys

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Recent studies have indicated that solar UV radiation is a significant stressor of coral assemblages in tropical and subtropical marine environments. Although increased exposure to UV has been tightly linked to stratospheric ozone depletion, there is evidence that UV exposure of corals also is strongly affected by changes in UV-absorbing substances in the overlying water. In particular, these results indicate that changes in chromophoric dissolved organic matter (CDOM) play a critically important role in controlling underwater UV exposure in the Florida Keys.

To define factors that affect UV exposure, depth profiles of underwater UV and visible irradiance were measured at a number of sites on cruises aboard the OSV P.W. Anderson during 1998 and 1999 and, as part of the experiments conducted during July 1999, at Eastern Sambo reef and nearby sites along transects from reef to shore. Water samples were obtained at these sites, and absorption and fluorescence spectra and chemical properties of the filtered water samples were obtained.

Using these irradiance and spectral data and the Setlow action spectrum for DNA damage, dose rates of DNA-damaging UV for various depths at Eastern Sambo and nearby sites were computed. Results of these analyses indicate that the coral reefs at Eastern Sambo were receiving considerable exposure to DNA-damaging radiation during July that was approximately 10–35 percent of surface UV irradiance at a depth of 3–4 meters (see Figure 1).

Water just inside the reef in Hawk Channel and water closer to land was considerably more opaque to UV due to higher concentrations of CDOM derived from long-range transport of CDOM from Florida Bay and the Everglades, from onshore mangroves, and from sea grasses in the channel. Water from Hawk Channel photobleached with loss of UV absorbance when it was exposed to simulated solar radiation.

These findings suggest that several interacting climatic and other factors are affecting UV exposure in the Florida Keys. Large-scale hydrologic manipulations of the Everglades, coupled with changes in precipitation patterns and runoff, likely have altered the amounts and variability of UV-protective CDOM in Hawk Channel and out over the coral reefs. Increased UV-B radiation at the surface of the water due to stratospheric ozone depletion can enhance photobleaching of the CDOM. This photobleaching effect, moreover, interacts with climate related factors such as warming-induced stratification or transport from CDOM-rich waters such as Hawk Channel, Florida Bay, and the Everglades.

To build on the initial results of this project, it is planned to: (1) more carefully examine the effects of water stratification and photobleaching on UV exposure at the corals sites; (2) compare spectral and other properties of the CDOM along transects in Hawk Channel and at coral reef sites to identify the major sources of CDOM; (3) conduct manipulations to identify factors that affect the photobleaching; (4) obtain continuous data on CDOM concentrations at Florida Keys sites such as Sand Key site based on fluorescence measurements; and (5) help develop methods and action spectra to relate these observations to changes in UV-specific damage to the coral and zooxanthellae DNA.

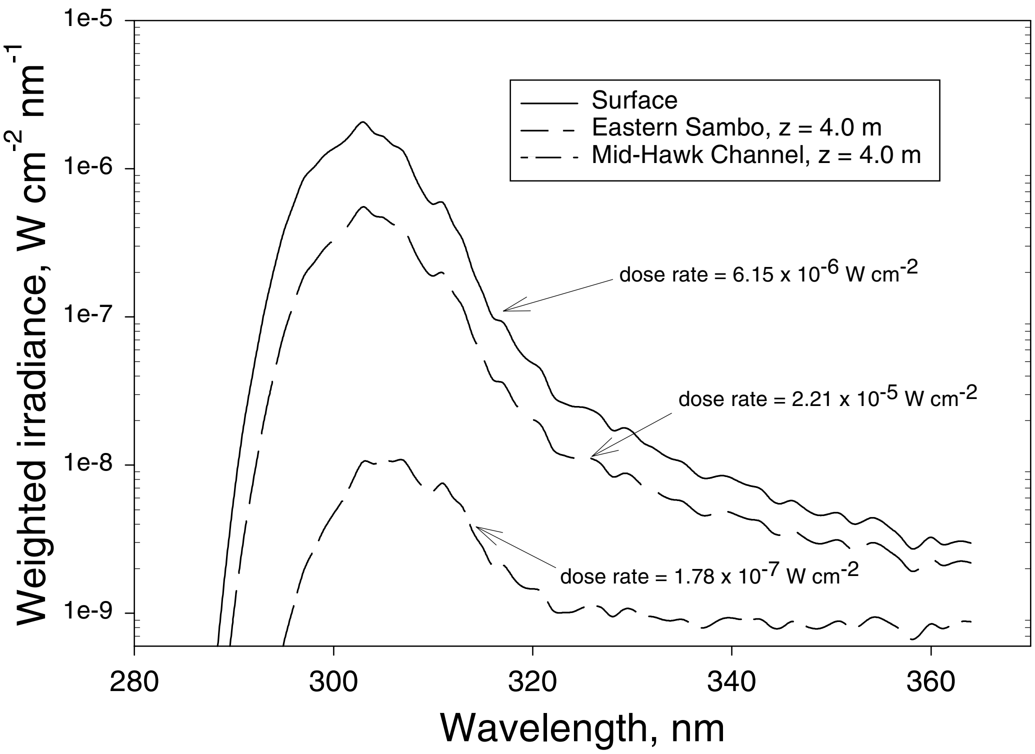

Figure 1. DNA-damaging weighted irradiance estimated for near the surface and at depth of 4.0 meters for Eastern Sambo and mid-Hawk Channel sites located in the Florida Keys.

An Autonomous, Moored Profiler: The Oceanic Remote Chemical/Optical Analyzer (ORCA)

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The purpose of this project is to establish a long-term water quality monitoring site in South Puget Sound. This system of fjords is fed by high-nutrient, oxygen-poor waters from the northeast Pacific. Although the main basin of Puget Sound is tidally mixed, parts of South Puget Sound are seasonally stratified and nutrient limited. The area currently is predominantly undeveloped, but it is expected to undergo extensive urbanization in the coming years. Because the area already is sensitive to oxygen depletion, eutrophication derived from long-term urbanization is of great water quality concern.

To monitor water quality in the area, the Washington State Puget Sound Ambient Monitoring Program (PSAMP) currently conducts monthly sampling at a suite of sites in Puget Sound via seaplane. The sampling, however, is coarse both temporally and vertically, making it difficult to distinguish local, tidal, diurnal, seasonal, and long-term effects.

For this research project, an autonomous, moored profiler called the Oceanic Remote Chemical/Optical Analyzer (ORCA) (see Figure 1) was developed to sense a variety of physical, chemical, and optical properties at high temporal and vertical resolution. This is an intensive effort to complement the extensive PSAMP one program. ORCA has three main components: (1) a three-point moored ATLAS toroidal float; (2) a profiling assembly on the float with a Tattletale-8 microcomputer, marine winch with slip rings, cellular system for remote programming and data download, batteries, and solar panels for battery recharge; and (3) an underwater sensor package at the end of a hydro-wire with Seabird CTD profiler, YSI dissolved oxygen electrode, Wetlabs transmissometer for particle concentration, and Wetlabs chlorophyll fluorometer for phytoplankton concentration.

At regular sampling intervals, ORCA's winch profiles the sensor package through the water column using pressure data from the CTD. ORCA has undergone extensive tests and was moored in Carr Inlet, South Puget Sound on May 26, 2000. Since that time, it has been gathering water quality data, detailing extensive stratification, oxygen depletion, and phytoplankton biomass variability in the area. These results will be compared with data collected aboard ship and during the PSAMP flights.

The next step is to add a suite of additional sensors: meteorological sensors (wind, temperature, humidity, irradiance), a Moss Landing Marine Labs chemical nitrate analyzer, a Pro-Oceanus chemical dissolved oxygen sensor, a Pro-Oceanus total dissolved gas sensor, an underwater photosynthetically active radiation (PAR) sensor, and an instrument for measuring spectral absorption and scattering coefficients (Wetlabs AC-9).

Figure 1. The Oceanic Remote Chemical/Optical Analyzer (ORCA).

Rhode River CISNet: Estuarine Optical Properties as an Integrative Response to Natural and Anthropogenic Stressors

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Light penetration in estuaries is governed by three factors that are broadly indicative of the health of the system and that are impacted by different human activities. Those factors are phytoplankton chlorophyll, an indicator of eutrophication caused by nutrient over-enrichment; suspended sediment, resulting from soil erosion and resuspension of bottom sediments; and dissolved color, which comes from decaying plant matter or certain industrial (e.g., paper mill) effluents.

The primary objective of this work is to utilize recent advances in monitoring of estuarine spectral optical properties to develop the capability to continuously monitor concentrations of factors that affect light penetration in the water. Synthesis of results will be aimed at developing estuarine optical properties as an integrated measure of response to perturbations on time scales ranging from individual storms or phytoplankton blooms, to seasonal, decadal, or longer responses to increased disturbance or to management efforts.

A system for continuously monitoring spectral absorption and scattering coefficients that utilizes a commercially available absorption/transmittance meter has been developed. Research is being conducted to interpret continuously monitored optical properties in terms of the three factors that govern light penetration. Additionally, manipulative experiments are being conducted to establish the response of *in situ* concentrations of chlorophyll, suspended sediments, and dissolved color to inputs of nutrients on event to interannual time scales. Finally, process level research is being conducted to examine the effects of solar UV radiation on nearshore plankton communities, as influenced by potential changes in estuarine optical properties.

A self-cleaning flow-through system has been designed to supply water to the optical monitoring instrument at hourly intervals. Monitoring data collected to date indicate that the system will be useful for resolving changes in phytoplankton chlorophyll over a wide range of time scales. Manual sampling over a 24-hour period in conjunction with the automated monitoring has verified that the system is measuring actual changes in optical properties. A mathematical procedure for determining the concentrations of light-absorbing materials has been developed, and shows great promise for interpreting the monitored data.

The system was in place during a major algal bloom in upper Chesapeake Bay in the spring of 2000. This red tide was widely publicized in the local media. The measurements obtained in this work will provide a quantitative estimation of the impact of this and similar events on light availability for submerged bay grasses during a critical period in their growth season.

In the coming year, data on the World Wide Web will begin to be posted. Creation of an FTP site that will be linked to the main research page of our local Web Site (www.serc.si.edu) is underway. Measurements of processes that result in nutrient inputs and eutrophication in the system will continue during the coming year. In addition, it is planned to construct a mobile unit for measurement of spatial variability in optical properties, to extend the measurements to other tributaries as well as the mainstem of Chesapeake Bay.

Figure 1. Technicians measuring underwater light spectra and light attenuation at the Rhode River CISNet Site.

CISNet for the Neuse River Estuary, NC: A Program for Evaluating Nitrogen-Driven Eutrophication Associated With Changing Land Use in a Coastal Watershed

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Over the past 2 decades, the Neuse River Estuary (NRE) has been plagued with nuisance algal blooms, hypoxia, toxicity, and fish kills associated with declining water quality. Increased nitrogen (N) loading associated with human population growth and land-use changes has been implicated. In response to mounting scientific evidence and public pressure, the State of North Carolina has legislated that a 30 percent reduction in external N loading (based on a mean 1990–1995 N loading "cap") be in place in the NRE by 2003. This represents a large-scale experiment that provides a unique opportunity to examine the effects of nutrient reduction on the ecosystem.

The objective of this CISNet program is to examine the impacts of external stressors—most prominently N loading—on the health of the NRE ecosystem. This requires development of time series of loading, transport, and spatially explicit indicator responses capable of separating long-term trends from interannual variability. The approach includes ongoing field-based studies of: (1) hydrography, nutrients, DO, light, and phytoplankton dynamics; (2) atmospheric N inputs; and (3) circulation in the NRE-Pamlico Sound system.

The focus has been on dissolved oxygen and the planktonic microalgal community, as they are easy-to-measure indicators of the biotic response of this ecosystem to external stressors. Dissolved oxygen depletion restricts benthic habitat and plays a causal role in fish kills. Phytoplankton dominate primary production and nutrient fluxes (e.g., in the Neuse-Pamlico Sound system, about 80 percent of the annual "new" C input is attributable to phytoplankton). A natural attribute of the phytoplankton, photopigments (determined by high-performance liquid chromatography [HPLC] coupled to spectrophotometry), are being used to rapidly and effectively distinguish major phytoplankton functional groups, including potentially harmful dinoflagellates and blue-green algae (cyanobacteria).

N loading over the past year was dominated by the extreme (~ 500 year) runoff event associated with Hurricane Floyd. The NRE responded to the organic and inorganic nutrient loading associated with this event with extensive bottom-water hypoxia that lasted several weeks and the development of an algal bloom (chlorophyll-a levels above 20 µg/l, compared with typical values of approximately 3–6 µg/l) at the mouth of the NRE (see Figure 1). This bloom has persisted into spring 2000 (i.e., 7 months), indicating a possible longer term (at least multiseasonal) trophic shift of the system in response to the hurricane's floodwaters. Diagnostic pigment analyses are being used to examine shifts in bloom composition and dynamics during this large-scale event.

Ecosystems such as the NRE may be expected to respond very differently to long-term, chronic nutrient stress and short-term, intense, episodic nutrient stress. The funding provided by CISNet is allowing for the expansion of earlier observational programs in the NRE to develop timeseries that are capable of separating long-term trends from high interannual variability. At the same time, this funding has allowed for the unprecedented opportunity to observe the ecological consequences of an extreme event in the NRE. Understanding the relative roles of chronic and event-based stressors is critical if a determination is to be made of the effectiveness of nutrient reduction in systems such as the NRE given the forecast of enhanced hurricane activity during the next 20 years.

Activities in 2000–2001 will include: (1) continuation of the ongoing field program, (2) expansion of the photopigment techniques as part of a continuous water quality monitoring program utilizing the NC Ferry system as "ships of opportunity" for sampling the Neuse River Estuary and Pamlico Sound, and (3) exploring ecosystem-scale quantification of photopigments (phytoplankton biomass) by remote sensing (aircraft and satellite) with Dr. L. Harding (University of Maryland).

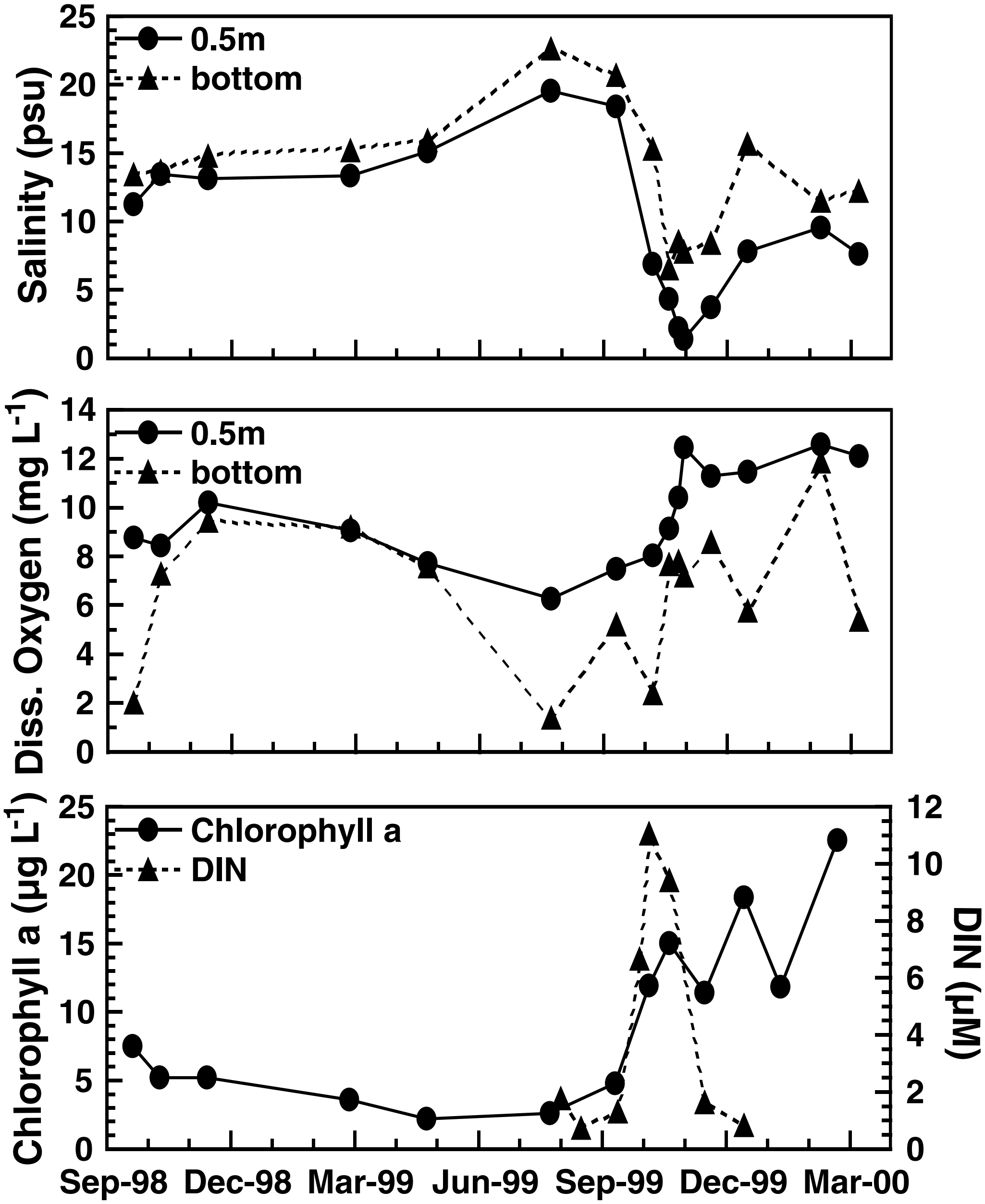

Figure 1. Response near the mouth of the Neuse River Estuary to Hurricane Floyd, which struck during September 15–16, 1999.

The Choptank River: A Mid-Chesapeake Bay Index Site for Evaluating Ecosystem Nutrient Management

Thomas C. Malone, J. Court Stevenson, J.C. Cornwell, L.W. Harding, and W.C. Boicourt
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The Choptank River has been largely impacted in the past by agricultural activities on the Delmarva Peninsula, especially over the last 50 to 100 years as fertilizer usage steadily increased until the 1980s, when efforts began to curtail nutrient inputs. This project focuses on monitoring via traditional shipboard sampling and retrospective data analysis as well as remote sensing approaches to determine estuarine responses to changing management strategies.

Water quality sampling in this project began in January 1999, in a particularly dry year, and is continuing under much wetter conditions in 2000. The data suggest that nutrient loadings were reduced in 1999, which undoubtedly was a factor in increasing the abundance of submersed aquatic vegetation in the shallows downstream. However, after the drought ended in spring, there were large dinoflagellate blooms *(Prorocentrum sp.)*, in several locations reflecting a flush of nutrients had occurred in the Choptank watershed. In addition, the Choptank bifurcates with the main arm having more wetland buffering from the other more agriculturally dominated Tuckahoe. The Tuckahoe has been understudied historically, but appears to have much different nutrient dynamics. It has particularly high nitrate loadings, reflecting the large agricultural inputs in this area.

The measurement of denitrification and calculations suggest that if well positioned in the landscape, tidal wetlands may be able to buffer as much as 80 percent of the incoming nitrate in groundwater and are a significant term in the budget in the mainstem of the Choptank. Thus, fringe marshes are very effective in reducing nitrogen loadings. Unfortunately, these are beginning to decrease in effectiveness because of high rates of sea level rise in this system, particularly over the last decade when rates have averaged 1.3 cm/yr.

It may not be surprising in view of this diminished function that the Choptank has shown slightly increasing nutrient concentrations over the last 20 years (despite massive attempts to clean up the Chesapeake). This is attributable to the fact that little has been done to actually reduce nitrogen and phosphorus loadings on the Eastern Shore of the Bay—other than creating grass buffer strips. More recently, winter cover crops have shown promise, and these are being used in increasing percentages in recent years to remove excess nitrogen fertilizers in the fall.

Another pervasive problem is the nitrogen and phosphorus in sewage sludge from the western shore wastewater plants, which may eventually be transported to tributaries such as the Choptank.

Current efforts are focused on trying to target "hotspot areas" in this tributary using a combination of older photographic as well as new techniques, such as hyperspectral analysis, to help guide increased efforts to control diffuse source pollution.

CISNet: Molecular to Landscape-Scale Monitoring of Estuarine Eutrophication

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Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Columbia, SC

This research project addresses three major hypotheses: (1) the composition and abundance of bacterial and phytoplankton communities will differ among estuaries as functions of nutrient availability; (2) bacterial and phytoplankton communities form associations that vary in complexity (species diversity) as a function of nutrient availability; and (3) at a landscape-scale, remote sensing of the concentration of chlorophyll in emergent wetland vegetation will provide a quantitative index of wetland condition and will demonstrate differences in nutrient loading among estuaries.

This work is focused on two South Carolina estuaries that have different nutrient loadings. Preliminary findings from the phytoplankton component of this research indicates that there are significant differences in phytoplankton communities between sites, and that these communities can be distinguished by using high-performance liquid chromatography (HPLC) to analyze the photopigments in water samples.

These observations indicate that diatoms generally respond favorably to high nutrient (especially NO_3) inputs, while marine cyanobacteria are adapted to oligotrophic conditions. It is envisioned that the combined applications of CHEMTAX and neural computing to HPLC pigment profiles will lead to a major advance in the current capabilities in determining phytoplankton community composition.

Using neural network (NN) sensitivity analysis, it was found that salinity, DOC, temperature, NH_4, sample position in the water column, and orthophosphate (OP) had significant associations with the pigments. The pigment violaxanthin, an accessory pigment of green algae, had strong, positive associations with NH_4 and orthophosphate. Developing NNs that can recognize the association between HPLC pigment profiles and phytoplankton taxonomy will allow for the forecasting of environmental conditions that promote different community types, including red tide blooms. Work on the bacterial communities using DGGE is progressing, and results from DGGE analysis indicate significant community differences within and between the two sites.

A second component of this project is developing linkages between remotely sensed images of coastal wetlands, fertility or nutrient status, and the chlorophyll density of the emergent wetland plant community. *In situ* biophysical (chlorophyll, biomass) data obtained at approximately 50 locations within each of the *Spartina alterniflora*-dominated study areas are being used to develop regression models between ecological variables and remote sensor data.

These models will be used to produce “greenness” maps depicting the functional health and productivity of the estuarine wetland vegetation. Maps of functional ecosystem health for each year of the study and a change detection analysis between 1999 and 2001 will be developed using this technique. This will provide baseline data for long-term monitoring of coastal estuarine wetlands, and the techniques being developed should be applicable to other coastal regions.

To develop tools for interpreting remotely sensed data, the light energy reflected from individual plant leaves is being examined with a spectroradiometer, which is providing information about the quality of light reflected from the plant canopy (see Figure 1), and is being correlated with related biophysical data, such as leaf area index (LAI), tissue nitrogen concentration, chlorophyll, and CO_2 exchange rates. These results should allow for a determination of which wavelengths are most sensitive to environmental variables such as nutrient availability. Then, it should be possible to develop models that can be used to interpret remotely sensed data such as multispectral ADAR images.

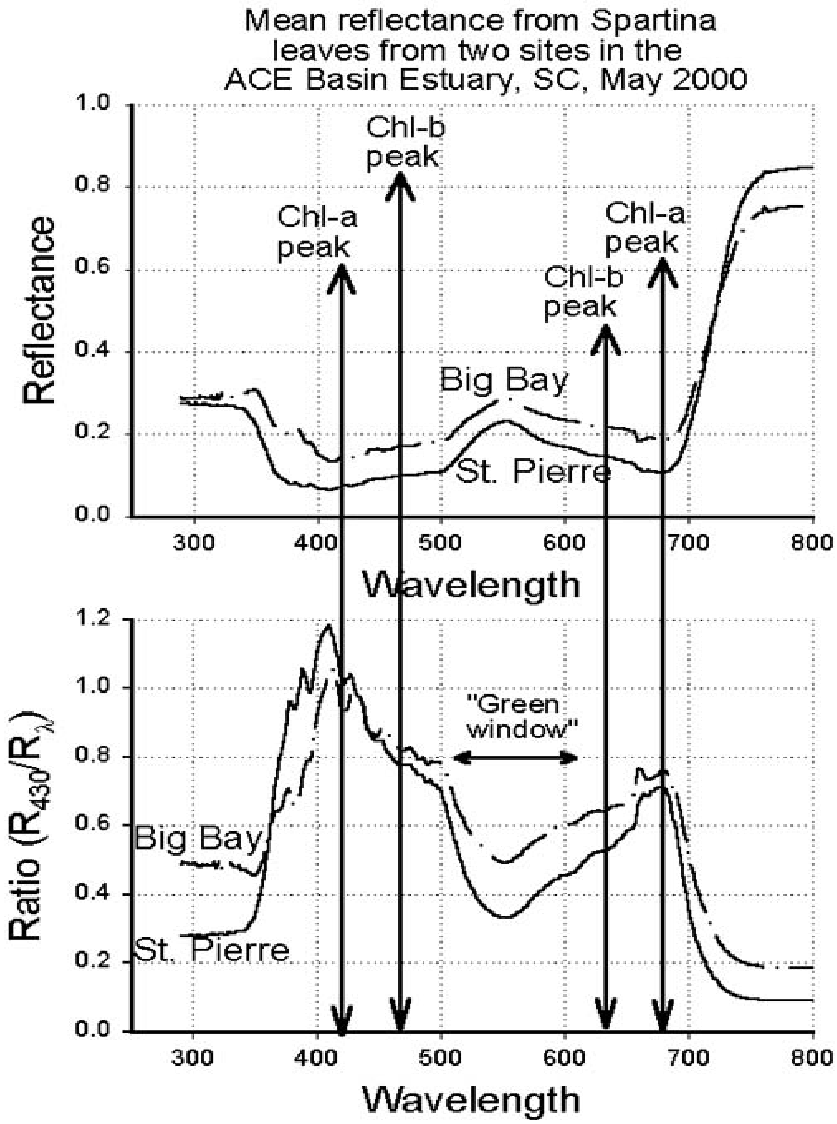

Figure 1. Examples of mean reflectance of light from Spartina leaves collected from two sites within the ACE Basin Estuary, SC. St. Pierre is a site that is impacted by a nearby marina and housing. Big Bay is not impacted. The top figure shows reflectance as a function of wavelength. In the bottom figure, reflectance has been standardized to the peak chlorophyll-a reflectance at 430 nm.

CISNet San Pablo Bay Network of Environmental Stress Indicators

S.Geoffrey Schladow[1], T.M. Young[1], I. Werner[2], B. Thompson[3], J.A. Davis[3], N. Nur[4], and D. Schoellhamer[5]

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The primary objective of this research project is to design an estuarine and wetland monitoring network that is temporally and spatially adequate to indicate ecological impacts of natural and anthropogenic stressors. Specific goals include: (1) determining spatial and temporal variability in anthropogenic and natural stressors; (2) developing and testing indicators of ecological health and understanding their natural variability; (3) identifying relations among indicators to refine their deployment; and (4) developing and demonstrating the monitoring network.

Flow, conductivity, temperature, depth, and optical backscatter are measured continuously for two 3-month periods during summer and winter at six sites. At 12 sites, water column and sediments are sampled monthly and analyzed for a suite of trace metal and organic compounds. Supercritical fluid extractability and aqueous desorption potential will be used to predict local contaminant effects on benthic organisms. Relationships between sediment-borne and water-borne contaminant fluxes and toxicity will be investigated using correlation analysis, principal components analysis, and multiple regression to identify statistical associations.

Biochemical indicators of ecological stress will be investigated in *Macoma balthica* and *Ampelisca abdita*. Monitoring sensitive biochemical and cellular indicators of deleterious effects should foretell subtle and possibly longer term consequences of exposure to chemicals in the environment. Sublethal effects will be compared to contaminant body burden and higher level effects such as growth and mortality. Ecological stress indicators include benthic community composition, contaminant bioaccumulation in fish tissue, and bioaccumulation and reproductive success for two bird species: Double-Crested Cormorants and Song Sparrows.

Methods for interpreting indicator outcomes will be facilitated by knowledge gained from the research on processes and mechanisms of flow and sediment transport, as well as relationships among indicators. Demonstration monitoring of these sites and the selected indicators will be performed at the end of Year 2 and early in Year 3, in coordination with the San Francisco Bay Regional Monitoring Program for Trace Substances (RMP). Flux data still are being analyzed; however, an interesting phenomena showed tidally averaged water and suspended-solids fluxes (SSF) can occur in opposite directions. This demonstrates that both water and SS fluxes are necessary to determine the fate and transport of dissolved and adsorbed contaminants. Desorption rate measurements are being conducted by combining contaminated sediment with clean background water and a sorbent resin (Tenax beads) in a vial that is continuously mixed. The resin beads serve as an infinite sink for hydrophobic organic contaminants, keeping aqueous concentrations always close to zero.

Cadmium and the insecticide esfenvalerate were chosen as model pollutants for laboratory studies. In addition, the effects of natural stressors (salinity and temperature variations) were investigated. *A. abdita* survival after 4 days of exposure was equal to controls in all Cd treatments, whereas all animals died when exposed to 0.1 and 0.5 μg/L esfenvalerate (nom. conc.). As this compound is hydrophobic, actual concentrations in these treatments are likely to be lower. Esfenvalerate is extremely toxic to *A. abdita*. Exposure to esfenvalerate did not affect survival of *M. balthica*. Tissue concentrations and bioaccumulation potential are being determined.

Fish are being sampled in three habitat types: open bay, tidal marsh, and freshwater creek. The two species sampled in 1999 were Staghorn Sculpin and Striped Bass. Both species are resident in the San Pablo Bay ecosystem and are predators that are exposed to relatively high concentrations of toxicants due to their trophic position. Contaminants being measured include mercury, selenium, PCBs and other trace elements, and organochlorine pesticides. Chemical analysis of the fish collected in 1999 currently is in progress.

Study plots were established for Song Sparrow breeding at four sites in three San Pablo Bay marshes. Nests also were monitored at two Suisun Bay tidal marshes and at the upland Palomarin field station. Cormorant eggs were collected from a colony on the Richmond Bridge. Chemical analysis of these samples is in progress. In samples from 1999, mercury concentration in fail-to-hatch Cormorant eggs were higher than in randomly collected eggs. For the Song Sparrows, preliminary analysis indicates that there is no significant difference among the sites in San Pablo Bay in terms of egg hatchability, nor a significant difference in hatchability between San Pablo Bay and the Suisun sites.

The main significance of the results to date is that they generally confirm the suitability of the approach selected. Many of the chemical analyses have yet to be completed, so spatial and temporal trends cannot be ascertained at present. The next major instrument deployment is being prepared, and Year 2 sampling of fish and birds also is underway. Later this year, the first demonstration monitoring exercise by the RMP will take place. A recent toxicity event within the boundaries of the study area is a major focus. It is planned to accelerate the analysis of some archived samples and to take additional samples in the vicinity of the event.

CISNet: Nutrient Inputs as a Stressor and Net Nutrient Flux as an Indicator of Stress Response in Delaware's Inland Bays Ecosystem

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This program is focused on the watershed of Delaware's Inland Bays, members of a common but understudied class of shallow estuarine ecosystems. The objective of this program is to document the sources and sinks of nutrients (nitrogen, phosphorus, and organic carbon) to and from the Bays. This watershed receives excessive nutrient fluxes from agricultural, municipal, domestic, and industrial sources. These lead to a number of undesirable consequences of eutrophication in the Bays. Nuisance algal blooms and episodes of anoxia are common in the Inland Bays.

The specific goals of this study are to: (1) determine the sources, magnitudes, and spatial and temporal variability of nutrient fluxes to the Bays; (2) assess the magnitude of nutrient sinks in this system; and (3) develop conceptual and simple quantitative models that relate these inputs and outputs to more easily measured and monitored hydrological forcing parameters such as precipitation, temperature, season, groundwater levels, and surface-water discharge.

The research is divided into six subprograms. These include components dealing with inputs from tributary streams, groundwater, and atmospheric deposition; inputs and outputs from the coastal ocean; outputs to sediments; and nutrient processing within the Bays. Progress has been made on all components of this effort, except for the outputs to sediments component, which is scheduled for 2001.

Baseflow discharges of nutrients from 14 tributary streams to the Bays continue to be sampled biweekly throughout the year. Tributaries were chosen on the basis of land use/land cover of their subwatershed and the significance of the total discharge. At six of these sites, stormwater discharges also have been sampled with funding from the Delaware Department of Natural Resources and Environmental Control. Precipitation chemistry is monitored on an ongoing basis at Cape Henlopen State Park, under the auspices of the NOAA-AIRMoN Program to determine the direct input of atmospheric nitrogen to the Inland Bays ecosystem. A second monitoring site, closer to the Bays, also has been established for this project.

An aerial thermal radiometer survey of the Bays was conducted in early 1999 to detect intense localized groundwater discharges. Sites identified by this survey have been visited to determine whether the observed thermal anomalies are associated with fresh groundwater seepage or other processes. Surveys of water and salt fluxes between Indian River Bay and the adjacent coastal waters and at other major channels within the ecosystem were conducted. Surface water samples are collected monthly during the spring, summer, and fall for the determination of changing nutrient distributions within the Bays.

In some tributaries, the concentrations of dissolved nutrients in baseflow appear to vary little; therefore, the net flux from these tributaries appears to be primarily dependent on the rate of water discharge. In other streams, the concentrations of nutrients appear to vary inversely with discharge. The atmospheric deposition of nitrogen provides between 14 and 24 percent of the total annual input to the Bays. Nitrogen deposition from the atmosphere is substantially higher in summer than winter. A number of sites have been identified for further detailed study of groundwater fluxes. One such site currently is being instrumented to document the spatial and temporal variability of discharge and the subsurface geology controlling the discharge. Tidal currents are dominated by the semidiurnal tides. Weaker semidiurnal tides produce significant modulations in the tidal currents.

Land use/land cover appears to control the character of nutrient fluxes from tributaries. It is not appropriate to use discharge alone as an indicator of the seasonal variability of nutrient fluxes from the watershed to the Bays. Atmospheric inputs of nitrogen during the summer may be ecologically extremely important, as surface waters in large areas of the Bays are N-limited during this period. The local contributions of nitrogen to the atmospheric budget are comparable in magnitude to all of the other sources. The data collected during Hurricane Floyd (September 1999) will allow for an examination of the impact of extreme hydrological events on nutrient flushing of the Inland Bays.

The bulk of the present research activity is concerned with the analysis of the baseflow and storm discharge results and putting this data into an easily accessible database management system (using Microsoft Access) to allow access by all of the CISNet collaborators and collaborators from state and federal agencies. Analysis of water, salt, and nutrient exchange continues, and analysis of the distributions of nutrients in the surface waters of the Bays is beginning. Preliminary geophysical surveys in support of the proposed sediment sampling are being conducted this year.

Additional assistance in meeting the goals of this program has been provided by the U.S. Geological Survey, the Delaware Geological Survey, the Delaware Sea Grant College Program, and the Delaware Center for the Inland Bays.

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