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Coastal Monitoring through Partnerships:

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EMAP Symposium Invited Speakers

Coastal Monitoring Programs: Results from Successful Partnerships I

COASTAL RESTORATION MONITORING IN LOUISIANA - PARTNERING TO MEET DATA NEEDS

Gregory D. Steyer and James B. Johnston

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The Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) has supported the implementation of 96 restoration projects in coastal Louisiana since 1990, encompassing over 1.07 million acres of wetlands and waters. A monitoring program was designed to quantitatively assess effectiveness of each project over a 20-year project life. Due to the temporal and spatial scale of this effort, the Louisiana Department of Natural Resources developed a partnership with the U.S. Geological Survey's National Wetlands Research Center to plan, implement, and manage the data collection, analysis, and information dissemination effort. Scientific input into experimental design, quality assurance and data interpretations are provided through peer-review by CWPPRA partners and the academic community. Although this collaboration has been effective in meeting monitoring mandates, opportunities exist for improvement in utilizing monitoring data through better feedback mechanisms and partnerships with the academic community and resource managers throughout the Gulf of Mexico.

Keywords: monitoring, wetland restoration, CWPPRA, Louisiana

ALABAMA'S COASTAL MONITORING AND ASSESSMENT PROGRAM - INTEGRATION AT THE STATE AND REGIONAL LEVEL

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During the summer of 1993, the Alabama Department of Environmental Management (ADEM) implemented an environmental monitoring and assessment program (ALAMAP-C) for Alabama's Coastal waters. ALAMAP-C has conducted annual surveys of estuaries to measure various environmental attributes, which can be interpreted or used as indicators of coastal water quality. The overall sample design and strategy for monitoring indicators of ecological condition was inspired by the U.S. Environmental Protection Agency's EMAP-Estuaries efforts in the Gulf of Mexico. The goal of this program is to provide information on the overall health of the estuarine environment and to track the health over time.

ALAMAP-C provides information on the ecological condition of Alabama's estuaries. Ecological health is being assessed by investigating the spatial distributions of physical, biological, and chemical indicators. The program determines what portions of estuaries support conditions that are favorable for both aquatic life and human use and it also attempts to determine why certain areas may not be favorable for either aquatic life or human use.

The spatial divisions used by ALAMAP-C have evolved through the years since its implementation but the program continues to investigate the ecological condition of Alabama's estuaries, including Mobile Bay, Perdido and Wolf Bays, the Alabama section of Mississippi Sound, and the tidal portions of the Mobile and Tensaw Rivers and delta system. ALMAP-C has successfully completed sampling efforts during the summer months of 1993-2000 in all of Alabama's near-coastal waters. In 1997 the first in a series of reports on the condition of the Alabama's estuaries was published. In 2001, data gathered since the first report will be examined and the findings will be presented to the public.

Keywords: ADEM, ALAMAP-C, EMAP-Estuaries, Alabama's estuaries

TAMPA BAY WATER QUALITY ASSESSMENT, A COLLABORATIVE LONG-TERM MONITORING EFFORT

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Water quality monitoring in Tampa Bay has been a collaborative effort by the Environmental Protection Commission of Hillsborough County (EPC), the City of Tampa (COT), Pinellas County (PC), and Manatee County (MC). EPC operates the most comprehensive program and has reported water quality since 1974 at over 50 sites covering Old Tampa Bay (OTB), Hillsborough Bay (HB), Middle Tampa Bay (MTB), and Lower Tampa Bay (LTB). COT began reporting water quality in HB and MTB in 1978, while PC and MC programs were initiated in 1991 (Boca Ciega Bay) and 1992 (Terra Ceia Bay/Manatee River), respectively. Through coordinated efforts spearheaded by the Tampa Bay National Estuary Program, environmental managers have made remarkable progress in coordinating their efforts geographically and standardizing sample collection and analytical methods. Local environmental managers formed the Southwest Florida Regional Ambient Monitoring Program (RAMP) group to develop consistent and comparable sampling and analytical techniques. The resultant monitoring network can provide unbiased assessments of status and trends in water quality through incorporation of probabilistic sampling techniques patterned after USEPA's EMAP methods. Monitoring results show considerable water quality improvement in most bay segments since the early 1980s, and improved conditions persisting through the 1990s. Spatial and temporal patterns and trends in water quality are reviewed based on nutrient, chlorophyll-a, dissolved oxygen, turbidity, and Secchi disk depth measurements. The importance and role of the monitoring network with respect to the Tampa Bay National Estuary Program's Comprehensive Conservation and Management Program is also discussed.

Keywords: Pinellas County, Hillsborough County, Manatee County, City of Tampa, Tampa Bay, water quality, monitoring, National Estuary Program, EMAP, chlorophyll, nutrients

EFFECTIVE MONITORING PARTNERSHIPS IN THE NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM

Maurice P. Lynch

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The National Estuarine Research Reserve System (NERRS), is itself a federal (NOAA)-state partnership. The 25 separate reserves have effectively partnered to develop a system wide monitoring program (SWMP) that has continuously measured water quality (salinity, temperature, dissolved oxygen, pH, turbidity) at two or more locations for the past several years. The reserves also operate one or more meteorological stations, usually in close proximity to the water quality stations as part of this program. SWMP data has been used to examine estuarine response to extreme weather events (hurricanes) and to examine dissolved oxygen in shallow water systems.

Many of the Reserves also routinely monitor water quality throughout their watersheds with the use of adult and school aged volunteers. The data collected are usually subjected to rigorous quality assurance/quality control procedures and in several states are used by local and state governments for management purposes. Several of the Reserves publish summaries of the data collected through these partnerships.

In addition to water quality, NERRS partnerships are monitoring Black Brant on their annual migrations from the Canadian Arctic to Mexico, Western Atlantic Shorebird migrations from Canada to South America, horseshoe crabs, oysters, red tide, exotic plants, tree diseases, fecal coliforms, oysters, fish, macro invertebrates and a host of other items. The NERRS relies on its partnerships, particularly those using volunteers for much of its monitoring. The Reserve infrastructure provides the continuity and quality control and assurance to ensure that the information collected by these largely volunteer efforts is scientifically defensible and properly archived.

Keywords: monitoring, water quality, volunteers, National Estuarine Research Reserve System, birds, animals, plants

TRANSLATING TWO DECADES OF PARTNERSHIPS INTO CHESAPEAKE BAY BASINWIDE MONITORING NETWORKS

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Since the early 1980s, partnership-based monitoring in the Chesapeake Bay region has evolved from a Maryland/Virginia/EPA tidal water quality monitoring focused on the mainstem Bay to now include a collaborative redesign of a basinwide non-tidal water quality network spanning six states and hundreds of regional and local jurisdictions. Throughout the two-decade history of monitoring program coordination in the Chesapeake region, there have been several keys to the successful, ongoing transition from hundreds of individual monitoring programs and data collection efforts to integrated baywide and basinwide networks. Beyond the partnership buzzword, there have been a number of operating principles learned, including:

- Shared quantitative restoration goals, management commitments and programmatic objectives agreed to at all levels;
- Multi-agency decision making on funding arrangements and allocations;
- Nested series of coordinating bodies empowered to make a full array of decisions directly impacting all the partners;
- Collaborative network designs whereby the partners gain more then operating independently;
- Underlying quality assurance infrastructure ensuring data quality amongst a multitude of data sources;
- Academic/management agreements promoting integration of research and monitoring;
- Structured, data analysis driving further network integration;
- Coupled airshed, watershed, and estuarine ecosystem modeling driving further integration with monitoring; and
- Commitment to distributed information management backed up through signed agreements.

Throughout the transition, partnership has taken on many new meanings.

Keywords: Chesapeake Bay, monitoring, partnerships, funding, monitoring networks

HIERARCHICAL NESTING OF PARTNERSHIPS AND PROBABILITY BASED SAMPLING TO DETERMINE LEVELS OF BENTHIC COMMUNITY DEGRADATION IN THE CHESAPEAKE BAY

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The extent of degradation of benthic communities of the Chesapeake Bay was determined by applying a previously developed Benthic Index of Biotic Integrity (BIBI) at six nested spatial scales. Allocation of sampling was probability based allowing areal estimates of degradation with known confidence intervals. The six spatial scales were (1) the tidal Chesapeake Bay and all its tributaries, (2) tidal Chesapeake Bay and tributaries within Virginia, (3) the James River within Virginia, (4) the Elizabeth River watershed within the James River, (4) the Southern Branch within the Elizabeth River, and (6) Scuffletown Creek within the Southern Branch. The areas covered by the six sampling strata varied from 10^{3} to 10^{-2} km^{2}. Areal estimates of degraded bottom may vary greatly at smaller spatial scales indicating where restoration efforts are most needed. In 1999 the percent degraded bottom, as indicated by poor benthic community condition, for the entire Chesapeake Bay was 48% and varied from 20% in the polyhaline stratum at the mouth the Bay to 72% in the Potomac River. The sampling programs and data needs were partnerships of various combinations of the US Environmental Protection Agency, the US Army Corps of Engineers, the Maryland Department of Natural Resources, the Chesapeake Bay Program Office of the Virginia Department of Environmental Quality, the Tidewater Regional Office of the Virginia Department of Environmental Quality and the Elizabeth River Project. The latter is a non-profit organization with participation from citizens, municipal governments, state agencies, academic institutions, federal agencies, the US military, and private industry.

Keywords: Spatial scales, Benthic Communities, Partnerships, Degradation, Benthic Index of Biotic Integrity, Chesapeake Bay, Contamination, Low Dissolved Oxygen

A Question of Scale: Coastal Monitoring Designs

TEMPORAL AND SPATIAL CONSIDERATIONS FOR WATER QUALITY MONITORING IN PACIFIC NORTHWEST COASTAL SYSTEMS

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The natural variability of indicators, and the causes contributing to this variation, are important considerations in the design and interpretation of monitoring programs to assess ecological status and human impact. Different indicators may vary on dissimilar spatial and temporal scales, thus requiring different monitoring strategies. Utilizing results from recent monitoring and research programs, we discuss variability in physical, chemical, and biological water quality parameters in coastal estuaries of Washington State over a range of spatial and temporal scales.

Within this region, waterbodies differ considerably in physical characteristics such as size, shape, and surrounding watershed, which leads to heterogeneity in water residence times, stratification intensity and persistence, and susceptibility to eutrophication. Furthermore, at a given location water properties are often extremely dynamic as a result of strong physical forcing over a wide range of temporal scales (e.g. tidal, seasonal, and interannual). For example, indicators such as phytoplankton biomass may vary more than tenfold within a 2-3 week period at a single location. Finally, Pacific coastal systems have strong connections with the Pacific Ocean, which exerts a large influence on water attributes. Upwelling events can bring intrusions of high nutrient low oxygen oceanic waters into these systems, circumstances that can mimic conditions commonly attributed to human caused eutrophication. This dictates that estuarine-oceanic coupling and large-scale climate variation is also a necessary consideration for interpetation of results from monitoring programs in this region.

Keywords: coastal monitoring, water quality indicators, spatial and temporal variability, Pacific estuaries

INTEGRATION OF PROBABILITY-BASED MARINE MONITORING AT THREE SPATIAL SCALES

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Monitoring of southern California coastal waters is presently conducted on three spatial scales to address different goals. The first sampling program focuses on the national scale, as EPA endeavors to achieve its national assessment through implementation of Coastal 2000. The second program is a regional assessment led by the Southern California Coastal Water Research Project, which has similar assessment requirements, but also seeks to compare conditions among subpopulations such as coastal urban runoff zones and offshore wastewater outfalls. The third sampling program monitors the effects of point-source discharges, where there are needs to map gradients away from an individual facility's discharge and to assess trends at sites along these gradients. These programs have been designed so that estimates can be generated using data from all of these programs. Integrating data from regional and national scales is facilitated by their common use of the EMAP sampling design, which is employed with stratification at varying densities in the regional scale monitoring. Local point source monitoring is based on a systematic sampling grid and its integration with regional monitoring requires merging spatial and inferential estimates. Indicators measured in all three programs are similar, but differences in methods require intercalibration to ensure comparability.

MONITORING COASTAL RESOURCES AT MULTIPLE SPATIAL AND TEMPORAL SCALES: LESSONS FROM EMAP

J. Kevin Summers

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In 1990, EMAP's Coastal Monitoring Program conducted its first regional sampling program in the Virginian Province. This first effort focused only at large spatial scales (regional) with some stratification to examine estuarine types. In the ensuing decade, EMAP-Coastal has conducted numerous regional monitoring efforts including most of the Nation's coastal resources culminating in a concurrent national survey in 2000-2001. Throughout this decade, EMAP has examined the role of differing spatial and temporal scales on the conduct, interpretability, and utility of information developed from these surveys. Using examples from the Mid-Atlantic Integrated Assessment (Chesapeake Bay), the Western Pilot (West Coast), the Integrated Water Resources Monitoring Program (Florida), and Coastal 2000 (National), the use of varying multiple scales for monitoring and the enhancement of then information resulting from the surveys are shown. Using nested spatial and temporal monitoring designs, the conceptual EMAP probabilistic approach is producing informative and useful data for the management of coastal resources at the national, regional, state and local scales.

USE OF PATH ANALYSIS TO INTEGRATE MULTIPLE STRESSORS

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The US Environmental Protection Agency (EPA) Region 4 initiated a project in 1992 to assess the effects of mercury contamination on the South Florida Everglades Ecosystem. This project was designed around the EPA Ecological Risk Assessment Framework and implemented using a statistical survey design to conduct synoptic surveys during the wet and dry seasons from 1994-1996. During this first phase of the project, soil, water, and biota were sampled at about 500 sites throughout the 9600 km^2 marsh to assess the effects of hydropattern, phosphorus loading, habitat alteration and mercury contamination on the marsh ecosystem. Three conceptual models were developed, one for each of three large spatial areas in the marsh, to describe the pathways and interactions among factors affecting fish mercury concentration.

Path analysis or structural equation models were developed based on these conceptual models. These structural equation models were used to determine the strength of associations among the variables included in the conceptual models. In general, there were significant differences in mercury pathways among the three areas. North of Alligator Alley, chemical interactions were important in affecting mercury bioaccumulation, while south of Tamiami Trail, biological pathways were important in affecting fish mercury concentrations. Additional analyses are continuing to investigate other conceptual models and to move from standardized to reduced form equations for use in projecting changes in fish mercury concentrations as a function of changes in stressor values.

Keywords: Structural equation models, statistical analysis, modeling, mercury, assessment

THE IMPORTANCE OF CONSIDERING SPATIAL ATTRIBUTES IN EVALUATING ESTUARINE HABITAT CONDITION: THE SOUTH CAROLINA EXPERIENCE

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The South Carolina Estuarine and Coastal Assessment Program (SCECAP) was initiated in 1999 to assess the condition of the state's coastal habitats using multiple measures of water quality, sediment quality, and biological condition. Sampling has subsequently been expanded to include components required for the Coastal 2000 Program. Habitats are classified as either "tidal creeks" (< 100 m in width) or larger "open water" bodies. Approximately 30 sites are sampled within each habitat during the summer months using a probability-based random sampling design. Results obtained from the first two years of sampling have documented significant differences in several water quality parameters (DO, pH, selected nutrients, turbidity, fecal coliform bacteria) and biological measures (e.g. chlorophyll-a, finfish and crustacean abundance and biomass) between the tidal creek and open water habitats. These differences highlight the value of partitioning shallow water habitats separately from the larger open water bodies traditionally sampled in estuarine monitoring programs, especially since tidal creeks serve as critical nursery areas for many species. Based on the differences observed, there is a clear need to identify different physical and biological thresholds for evaluating the condition of each habitat type. The 1999-2000 data also indicates that single point-in-time measures of some variables (e.g. DO) are not always a good indicator of longer-term averaged measurements collected at a particular site.

Keywords: water quality, sampling design, finfish, habitat

A MULTIPLE REFERENCE MONITORING APPROACH FOR EVALUATING WETLAND RESTORATION TRAJECTORIES

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Wetland restoration efforts conducted in Louisiana under the Breaux Act require monitoring the effectiveness of individual projects, as well as monitoring the cumulative effects of all projects in restoring, creating, enhancing, and protecting the coastal landscape. Traditional paired-reference monitoring approaches have been ineffective due to difficulty in finding comparable reference sites. A multiple reference approach is proposed that uses aspects of hydrogeomorphic functional assessments and probabilistic sampling. This approach includes a suite of reference sites that encompass the range of ecological condition for each stratum, with projects placed on a continuum of conditions found for that stratum. Trajectories in reference sites through time are then compared with project trajectories through time. Issues regarding selection of indicators and strata, and determination of sample size will be discussed. The approach proposed could serve as a model for evaluating wetland ecosystems.

Keywords: monitoring, wetland restoration, Louisiana, reference, HGM

Biological Indicators: Research Advances and Challenges for Implementation

RESPONSES OF DEMOGRAPHIC, MORPHOLOGICAL, AND CHEMICAL CHARACTERISTICS OF TURTLE-GRASS, *Thalassia testudinum,* TO EL NINO RUNOFF: AN UNEXPECTED TEST OF INDICATORS

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We examined the response of demographic, morphological, and chemical characteristics of turtle grass (*Thalassia testudinum)*, to much-higher-than-normal rainfall in the winter of 1997-1998. Turtle grass was selected as our indicator species because it is the dominant seagrass species in the Gulf of Mexico and because it is highly vulnerable to declines in water quality. The El Nino rainfall of 1998 triggered widespread and persistent phytoplankton blooms and provided an excellent opportunity to test the responsiveness of Thalassia to the decline and subsequent improvement of water quality and clarity in four West Florida estuaries. The responses of several Thalassia morphological parameters were temporally and spatially consistent with light stress induced by El Nino runoff. However, some parameters lacked the discriminating power necessary to be useful indicators. Larger sample sizes might improve the power of those parameters in future studies, but, given our sampling program, Thalassia shoot density, blade width, blade number, and shoot-specific leaf area were the most promising measures of light stress. Spatial and temporal variation patterns of most chemical parameters- elemental ratios and stable isotope ratios- were not consistent among sites. The chemical parameters which exhibited the most spatially and temporally consistent variation , as well as discriminating power, were rhizome sugar, starch, and total carbohydrate concentrations. Because changes in shoot density, as well as water clarity, affect rhizome carbohydrate levels, a parameter based on Thalassia shoot density and rhizome carbohydrate levels together is probably more useful than either parameter alone as an indicator of seagrass health.

BIOEFFECT THRESHOLDS FOR PREDICTING RISKS OF BENTHIC IMPACTS IN RELATION TO SEDIMENT CONTAMINATION ALONG THE U.S. ATLANTIC AND GULF OF MEXICO COASTS

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Matching data on sediment contaminants and macroinfauna from 1,349 samples collected as part of EMAP in estuaries along the U.S. Atlantic and Gulf of Mexico coasts were used to define thresholds for evaluating risks of benthic community-level impacts in relation to multiple-contaminant exposure. Sediment contamination was expressed as the mean ratio of individual contaminant concentrations relative to corresponding sediment quality guidelines (SQGs), including Effects Range-Median (ERM) and Probable Effects Level (PEL) values. Benthic condition was assessed using multi-metric biotic indices developed for each region. Cumulative frequencies of stations with an impaired benthic assemblage were plotted against ascending values of the mean ERM and PEL quotients. Based on the observed relationships, contaminant levels were divided into four ranges corresponding to either a low, moderate, high, or very high incidence of impaired benthic condition. Results showed that condition of the ambient benthic community provides a reliable and sensitive indicator for evaluating the biological significance of sediment-associated stressors. Upper thresholds, marking the beginning of the contaminant range associated with the highest incidence of benthic impacts (73-100% of samples, depending on the region and type of SQG), were well below those linked to high risks of sediment toxicity as determined by laboratory survival tests conducted with single species. Measures of the condition of the ambient benthic community reflect the sensitivities of multiple component species and life stages to persistent exposures under actual field conditions. Similar results were obtained with preliminary data from the west coast (Puget Sound).

Keywords: Benthic indicators, sediment quality assessment and forecasting, sediment contamination, predicting benthic stress, U.S. Atlantic and Gulf of Mexico estuaries

FORAMINIFERS AS BIOINDICATORS IN CORAL REEF ECOSYSTEMS: THE FoRAM PROTOCOL

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Coral-reef communities are threatened worldwide. Resource managers urgently need indicators of the biological condition of reef environments that can relate data acquired through remote-sensing, water quality and benthic-community monitoring to stress responses in reef organisms? Reef-dwelling foraminifera, especially taxa that host algal symbionts, show great potential for use as indicators of reef vitality:

- Foraminifera are widely used as environmental and paleoenvironmental indicators.
- Zooxanthellate corals and foraminifera with algal symbionts have similar environmental requirements.
- A readily identifiable and abundant genus, *Amphistegina,* exhibits similar stress responses to those found in corals.
- The relatively short life spans of foraminifera as compared with colonial corals facilitates differentiation between long-term decline and episodic stress events.
- Foraminifers are relatively small and abundant, permitting statistically-significant sample sizes to be collected quickly and relatively inexpensively.
- Collection of foraminifera has minimal impact on reef resources.

The “FoRAM” (Foraminifers in Reef Assessment Monitoring) protocol is the synthesis of 30 years of research on reef sediments and reef-dwelling larger foraminifera. The three-tiered procedure includes sediment-constituent analysis, which can address questions of historical change and reference-site suitability; analysis of live foraminiferal assemblages to indicate the suitability of sites of concern for organisms with algal symbionts; and analysis of *Amphistegina* populations for evidence of specific stressors to which these foraminifers respond similarly to corals. Future research to identify and quantify physiological and molecular responses to specific stressors will further facilitate use of larger foraminifers as bioassay organisms in reef research.

Keywords: bioindicators, coral reefs, foraminifera, zooxanthellae, algal symbiosis

BURROWING MAYFLIES (*HEXAGENIA*) AS INDICATORS OF ECOSYSTEM HEALTH

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The U.S. Environmental Agency and Environment Canada have hosted three State of the Lakes Ecosystem Conferences (SOLEC) since 1966 to encourage the development of Great Lakes indicators of ecosystem health. These indicators are to be used for reporting to the governments of the United States and Canada and the public on progress in restoring and maintaining the chemical, physical, and biological integrity of the Great Lakes ecosystem, as called for in the Great Lakes Water Quality Agreement between the two countries.

Here we report on the development of a SOLEC indicator based on burrowing mayflies (*Hexagenia*). Burrowing mayflies are large aquatic insects that spend 2-3 days as winged adults and the rest of their 2-year life span as nymphs burrowed in the lake bed. Burrowing mayflies were selected because they (1) were historically abundant in unpolluted, soft-bottomed mesotrophic habitats throughout the Great Lakes, (2) are intolerant of and were extirpated by pollution in most of those habitats in the 1940s-1950s, (3) have shown the ability to recover almost completely in one of those habitats following pollution abatement, (4) have highly visible mating swarms of winged-adults, that can carry the message directly to an informed public that the source water body is healthy, and (5) are ecologically important as bioturbators of lakebed sediments and as trophic integrators that link detrital energy resources directly to fish, which feed preferentially on them. A recently completed study of burrowing mayflies in the connecting waterway between Lakes Huron and Erie showed that annual production (P) could be estimated by regression analysis from the mean annual biomass (B) by the equation $P = 2.4\ B$ ($R^2 = 0.94$). The addition of data from other published studies in North America to the analysis changed the relation slightly to $P = 2.5\ B$ ($R^2 = 0.96$), showing the relation was broadly stable and suggesting it could be used to estimate annual production of burrowing mayflies over most of their northern range. Further sampling and analysis showed that the mean annual biomass could be estimated by the equation $B = 0.47$ Bjune ($R^2 = 0.8$), where Bjune represented the biomass of nymphs longer than about 16 mm in samples collected in June. This approach minimizes the sampling and sample processing effort required to use *Hexagenia* as a reliable, quantitative indicator of ecosystem health.

INTERACTIVE EFFECTS OF FOOD WEB ALTERATIONS AND CONTAMINANT EXPOSURE ON FISH POPULATIONS IN THE SAN FRANCISCO ESTUARY: IDENTIFYING THE RELEVANCE OF ECOLOGICAL INDICATORS

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Fishes of the San Francisco Estuary have been subjected to rapid changes in the abundance and composition of zooplankton food resources due to invasive species and exposure to pesticides in urban and agricultural run-off. These factors can act alone or synergistically to affect growth rates, year-class success, and future reproductive success. We quantified the mechanisms underlying "condition" of larval striped bass by developing indices in the laboratory based on morphometry and histopathology. Indices were then implemented in field-studies in conjunction with monitoring surveys of fishes and water chemistry. In the field, these indices successfully distinguished the relative importance of pesticide exposure from poor feeding success. We recently increased the power of this approach by tying in evaluations of fish otoliths to assess growth rate and pattern, as well as genetic eco-toxic responses to contaminant exposure for individual larval and juvenile delta smelt, a threatened species. For individual specimens, histopathological analyses of hepatic tissue indicate site-specific abnormalities consistent with a contaminant etiology. Comparison of growth rates and DNA strandbreaks as measured by an electrophorectic assay (the Comet Assay) among sites indicates lower growth rates as well as higher percentages of damaged DNA at the sites in which abnormal histological condition was also identified. In addition, water chemistry evaluations indicate elevated, yet sublethal, concentrations of pesticides at the time of specimen collection. Collectively, these integrated studies suggest an approach for quantifying biological indicators that can be translated from individuals to populations, as well as readily incorporated into monitoring programs.

Keywords: Condition indices, histopathology, otolith, DNA strandbreaks, Comet Assay, biological indicators, fish growth and mortality

BIOLOGICAL INDICATORS FOR MONITORING SALT MARSH STRUCTURE AND FUNCTION: FOCUS ON VEGETATION AND NEKTON

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Salt marsh ecosystems are changing in response to sea level rise, altered tidal flow, nutrient enrichment, invasive species, and other natural and human-induced agents. Long-term monitoring of the fundamental biological components of salt marshes, such as vegetation and nekton, is essential to understanding how habitat support function is responding to environmental stressors. For Cape Cod National Seashore (MA), a comprehensive long-term coastal monitoring program is under development, with all ecosystem types represented (estuaries and salt marshes, freshwater ponds, dunes and spits, and maritime forests). For salt marshes, quantitative methods have been developed and field-tested for evaluating changes in the species composition and relative abundance of vegetation and shallow-water nekton. The overall program is designed so that many of the individual monitoring protocols (e.g., watershed development, nutrient loading, geomorphology, nekton, marsh vegetation, etc.) are tightly linked. Effective management of salt marsh habitat functions is best achieved when managers can detect changes in species composition or abundance, and also have an appreciation for the human-induced or natural factors contributing to those changes. The salt marsh vegetation and shallow-water nekton sampling protocols developed for Cape Cod National Seashore are being successfully applied at other coastal units throughout the northeastern US. Monitoring vegetation and nekton indicators, using similar methods at numerous sites along an impact gradient, may enable definition of ecologically acceptable thresholds of change and targets for habitat restoration.

Coastal Monitoring Programs: Results from Successful Partnerships II

REGIONAL MONITORING OF THE SHORELINE MICROBIOLOGY OF THE SOUTHERN CALIFORNIA BIGHT: DIALOGUE, COOPERATION, AND RESULTS

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An extensive amount of routine bacteriological monitoring is performed along the coastline of Southern California. However, most beach water quality monitoring is focused on “problem areas”. In order to examine beach water quality from a regional perspective, more than 20 agencies, institutions, and laboratories that perform routine bacteriological monitoring in the Southern California Bight (SCB) banded together to perform 3 studies. Two of the studies spanned 5 weeks each, during August/September 1998 and February/March 1999, and were conducted during dry weather. In February 2000, a single-day study was conducted immediately following a large storm event. All three studies involved stratified random sampling of the entire SCB for total coliforms, fecal coliforms and enterococci. The two studies conducted during dry weather indicated good water quality along the coastline (> 90% of the shoreline-mile-days were below indicator bacteria thresholds). Even during dry weather, storm drains were identified as problem areas, with 40% of the shoreline adjacent to storm drains exceeding thresholds, demonstrating the detrimental effects of non-point source urban runoff. During the storm event study, 58% of the shoreline miles exceeded thresholds, demonstrating the striking impacts of urban runoff on the entire coastline. These three studies were the result of dialogue and cooperation between more than 30 organizations comprised of City and County water quality agencies and sanitation districts, academic institutions, volunteer and non-profit organizations, State and Regional Water Quality Boards, and Mexican scientists. The scientific results of these three cooperative studies have already had bearing on decision-making in water quality management.

Keywords: water quality, regional monitoring, microbiology

COASTAL 2000 AND THE 21ST CENTURY SCIENCE/MATH TEACHER SKILLS PROJECT: A PROFESSIONAL DEVELOPMENT EXTENDED PARTNERSHIP

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COASTAL 2000 monitoring and research provided a unique opportunity to combine K-12 education with Congressman Rush Holt's *21st Century Science/Math Teacher Skills Project.* The Holt initiative seeks to reduce teacher isolation from the scientific community, improve teacher retention rates, improve curricula in the sciences, and serve as a model for national reform in high school science and mathematics education. The *21st Century Project* established partnerships among business, industry and government and local school districts to place high school teachers into "real-world" coastal research programs. NJMSC's proposal, linking *Coastal 2000* to the initiative, was one of six projects selected for funding by Monmouth University, manager of the *21st Century Project*. Through C*OASTAL 2000* research, teachers had the opportunity to work side-by-side with scientists in field and laboratory aboard the NJMSC's research vessel, the *R/V Walford*. In summer of 2000, two New Jersey high-school teachers assisted scientists with research tasks on Delaware Bay including sample collection, laboratory analysis, and data interpretation. The teachers also worked with NJMSC Education Program staff to translate their *COASTAL 2000* experiences into learning modules, case studies and laboratory exercises for use in formal and informal educational settings. The teacher's experiences and the impact this partnership has had on their teaching, their students, and their school will be addressed, including a review of curricular materials produced.

Key Words: Coastal 2000, professional development, extended partnership, K-12 education, coastal research, curricular materials

OREGON COASTAL EMAP – PARTNERSHIPS AND LESSONS LEARNED

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The State of Oregon is participating in the five-year Western Pilot Coastal EMAP and has completed the first two years of field sampling. Oregon views this effort as an initial development and testing phase of ecological indicators and monitoring designs for an ongoing coastal program. Oregon's coastal environmental issues include introductions of nonindigenous species, destruction and alteration of habitat, eutrophication and harmful algal blooms, dredging and other sedimentation-related issues, direct and indirect impacts from fin- and shellfish harvest, toxic contamination, hydrologic modifications, and bacteria and viral contamination. The Oregon Coastal EMAP efforts are being conducted within the context of the Oregon Plan for Salmon and Watersheds, Oregon's response to the threat of Endangered Species Act salmon species listings. Successful implementation of the Oregon Coastal EMAP has required a cooperative partnership with state and federal natural resource agencies. As a participant in the EMAP pilot, Oregon has gained capabilities for estuarine and riverine sampling, expanded the laboratory's analytical capabilities, developed cooperative relationships with other state environmental agencies, received crucial training in handling formalin from Washington staff, and participated in a technology transfer workshop sponsored by EPA. Challenges have included: clear communication of data quality expectations and program obligations from EPA; data tracking, transfer, and management; and obtaining state and federal collection permits in light of current ESA listings.

Key words: ecological indicators, monitoring design, data management

ASSESSMENT OF INTERLABORATORY VARIABILITY OF AMPHIPOD SEDIMENT TOXICITY TESTS IN A COOPERATIVE REGIONAL MONITORING PROGRAM

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Marine sediment toxicity tests are widely applied in monitoring programs, yet relatively little is known about the comparability of data from different laboratories. The need for comparability information is increased in cooperative monitoring programs, where multiple laboratories (often with variable skill levels) perform toxicity tests. An interlaboratory comparison exercise was conducted among seven laboratories in order to document the comparability of sediment toxicity measurements during the Bight'98 regional sediment survey in southern California. Sediments from four stations in Los Angeles and Long Beach Harbors were tested using a 10-d survival test of the amphipod *Eohaustorius estuarius*. All laboratories successfully performed the sediment test and associated reference toxicant test. Statistically significant differences were found in mean amphipod survival rates among some laboratories for the field-collected sediments, but no consistent significant bias was observed. Testing by multiple laboratories did not appear to reduce the precision of the reference toxicant results. The laboratories demonstrated excellent concordance (Kendall's W = 0.91) in ranking the field-collected sediments by toxicity. Agreement on classifying the sediments into categories (nontoxic, moderately toxic, and highly toxic) based upon the percent of survival was best for highly toxic sediments. An analysis of test precision based upon the variance among replicates within a test indicated that the measured survival rate for a sample may vary by up to 12 percentage points from the actual response.

Keywords: sediment toxicity, southern California, variability, amphipod, regional monitoring

MAKING PERFORMANCE-BASED CHEMISTRY WORK: HOW WE CREATED COMPARABLE DATA AMONG 10 LABORATORIES AS PART OF A SOUTHERN CALIFORNIA REGIONAL ASSESSMENT

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In 1998 we surveyed the coast of Southern California collecting more than 300 samples of benthic sediments and fish tissues. Prior to sample collection and analysis, 10 public and private laboratories including the University of Baja California participated in discussions and inter-laboratory comparisons to develop and attain performance goals that each laboratory was required to meet before they were approved to analyze samples. This paper will describe the process used to bring multiple laboratories, using independent extraction and analysis methods, from results that were significantly different from each other to data that met and exceeded our goals. The process included selecting target parameters, developing our own reference material, and exchanging technical information between chemists in a cooperative effort to improve the overall quality of all the laboratories.

Keywords: Intercalibration, DDT, PCB, PAH, Trace Metals, Performance-Based Chemistry, QA/QC, Sediment Chemistry, Tissue Chemistry

ASSESSING MARINE BENTHIC INVERTEBRATE DATA QUALITY AND ENSURING TAXONOMIC UNIFORMITY DURING MULTI-LABORATORY PROJECTS: THE SOUTHERN CALIFORNIA EXPERIENCE

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Although the results of studies measuring anthropogenic impacts on marine benthic invertebrates depend on the ability of taxonomists to consistently discriminate, identify, and count organisms in a repeatable manner, there have been few attempts to assess the quality of benthic identification and enumeration efforts. In Southern California Regional Monitoring Programs conducted in 1994 and 1998 the quality of data was assessed by reanalyzing 10% of the samples at a different laboratory and comparing results. In 1994, approximately 80% of 92,570 organisms were identified to species with an overall error rate of 3.4% in numbers of taxa, 2.1% in organism counts, and 4.7% in identification accuracy. About 13% of the re-analysis records contained identification or counting errors. The 1998 laboratory program showed a small, but noticeable, improvement with 83% of 153,682 organisms identified to species. Similar improvements in the error rates are expected once the reanalysis data are finalized. These measurements of error are the first data available to develop control limits for identification and enumeration accuracy in multi-laboratory efforts. In another quality control step designed to ensure uniform nomenclature, participating taxonomists compared their data habitat-by- habitat and name-by-name. The southern California program increased communication among participating taxonomists, thereby improving the quality and consistency of the data. It also helped identify advantageous process changes; in 1998, consistency was improved by sending three groups of organisms previously identified at individual laboratories to single experts for identification.

Satellite and Aircraft Remote Sensing of Coastal Waters: Potential Real-time Applications

AIRCRAFT REMOTE SENSING OF OCEAN COLOR IN CHESAPEAKE BAY TO ESTIMATE CHL-A AND PRIMARY PRODUCTIVITY

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Chlorophyll (chl-a) and primary productivity are key properties of estuarine and coastal waters that may serve as indices of ecosystem health. We have used aircraft remote sensing of ocean color for over a decade (1989-2001) to recover data on chl-a (and temperature) in Chesapeake Bay. The impetus for this work is to improve spatial and temporal resolution of phytoplankton biomass expressed as chl-a, in collaboration with on-going shipboard monitoring programs that provide *in-situ* data for calibration and validation. Several instruments have been used, including NASA's Ocean Data Acquisition System (ODAS – 1989-95), and Satlantic's SeaWiFS Aircraft Simulator (SAS II, SASIII – 1995-2001). Data are collected on over-flights of the Bay conducted at approximately weekly to twice-weekly intervals on the main stem Bay, and monthly on two tributaries, the Choptank and Patuxent Rivers, that drain agricultural and suburban watersheds, respectively. Recent extremes of freshwater flow from the major tributaries of the Bay have generated extremes of chl-a that we have quantified using remotely sensed observations. We present chl-a distributions for several years (1995-2000) to document the strong seasonal and inter-annual variability of chl-a that is driven by meteorological forcing and anthropogenic nutrient loading. These data show relatively low chl-a in the main stem Bay and tributaries in years of reduced flow and nutrient loading (1995, 1999), and high chl-a in years of high flow and nutrient loading (1996, 1997, 1998, 2000). Depth integrated models of primary productivity (PP) developed for Chesapeake Bay have recently been applied to remotely sensed chl-a observations to estimate the Bay-wide distribution of net and gross PP. We show early results to demonstrate the improved resolution of PP that can be obtained using this approach.

THE POTENTIAL APPLICATION OF MODIS IN COASTAL MONITORING

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The first Moderate Resolution Imaging Spectroradiometer (MODIS) instrument was launched in December 2000 onboard the Terra satellite. A second MODIS will be carried into space on Aqua later this year. In this presentation, I will begin by describing MODIS's capabilities for coastal ocean remote sensing. MODIS has 36 spectral bands, and is designed to image clouds, land, and ocean features with complete global coverage every two days. Of the MODIS bands, there are 9 bands in the visible and near infrared region that have been specifically designated as ocean color bands. In addition, there are bands in the thermal infrared region that can be used to determine sea surface temperature. Like the Sea-Viewing Wide Field-of-view Sensor (SeaWiFS), all of these ocean bands have 1 km spatial resolution, and thus their ability to resolve features close to shore is somewhat limited. However, there are 7 additional bands with higher resolution (2 at 250 m, and 5 at 500 m). In this talk, I will present results by members of the MODIS Science Team who have explored ways of using the higher resolution bands for coastal applications. In addition, I will demonstrate how a time series of ocean color data can be used to define the spatial extent of fluvial influence near the mouth of a river. Finally, I will show how we select and blend algorithms for coastal ("case 2") waters that are specifically designed to account for the special mix of constituents found in a particular region.

Key words: ocean color, remote sensing, MODIS, spatial resolution

REMOTE SENSING FOR OPERATIONAL MONITORING OF COASTAL AND ESTUARINE ENVIRONMENTS: LESSONS FROM NARRAGANSETT BAY, RHODE ISLAND

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The key strengths remotely sensed data are the wide area coverage, instantaneous measurement, and that the data can be related to the physical and biological properties of the water. Satellite data are low cost but the temporal and spatial resolution may not be sufficient for some applications. Aircraft observations can be tailored to specific needs but the costs and data processing requirements are higher. Since these measurements are limited to near-surface waters they are best incorporated as an element of an integrated program. Examples of both monitoring and research applications derived from remote sensing observations of Narragansett Bay will be presented.

Temperature is a fundamental property of marine systems and a measurement readily made remotely with an estimated precision of 0.5 C or better. If temperature measurements have been acquired over a sufficiently long period of time, space for time substitutions can be used to identify environmental impacts on estuarine waters. High temporal and spatial resolution observations made from aircraft provide unprecedented views of the effects of tidal motions and mixing on temperature distribution. Ultimately such observations are best integrated with modeling to provide validation information or to be used in assimilation. Hyperspectral observations provide great promise for quantifying the concentrations of chlorophyll, suspended sediment, dissolved organic matter, and organic particulates. In addition such data have great utility in shallow environments for identifying bottom properties and the location of submerged aquatic vegetation. Examples of both will be presented.

A PILOT PROJECT TO DETECT AND PREDICT HARMFUL ALGAL BLOOMS IN THE NORTHERN GULF OF MEXICO

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More timely access to data and information on the initiation, evolution and effects of harmful algal blooms can reduce adverse impacts on valued natural resources and human health. To achieve this, a workshop was held to develop a user-driven, end-to-end (measurements to applications) observing system for the northern Gulf of Mexico. A key strategy is to utilize existing state, federal and academic programs in a coordinated network (see http://www.csc.noaa.gov/cts/coos/), which will require an unprecedented level of collaboration and partnership across agencies. Resource managers charged with protection of public health and aquatic resources require immediate notice of harmful algae events and a forecast of when , where and what adverse effects will likely occur. Further, managers require analyses and interpretations, rather than raw data, to make effective decisions. Consequently, a functional observing system must both collect and transform diverse measurements into usable forecasts. Data needed to support development of forecasts will include such properties as sea surface temperature, winds, currents and waves; precipitation and freshwater flows with related discharges of sediment and nutrients; salinity, dissolved oxygen, and chlorophyll concentrations (*in vivo* fluorescence); and remotely-sensed spatial images of sea surface chlorophyll concentrations. These data will be provided by a mix of discrete and autonomous *in situ* sensing with near real-time data telemetry, and remote sensing from space (SeaWiFS), aircraft (hyperspectral imagery) or land (high-frequency radar). Ultimately, calibration across these platforms could provide a 4-dimensional visualization of harmful algae events in a time frame beneficial to resource managers.

Keywords: Remote sensing, harmful algal blooms, observing systems, *in situ* sensing, environmental monitoring

TEMPORAL MONITORING AND SPATIAL MAPPING OF SURFACE OPTICAL PROPERTIES IN ESTUARIES AS AN AID TO INTERPRETATION OF REMOTE SENSING DATA

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The optical properties of estuaries, which determine the light received by remote sensing platforms, are governed by three factors that are broadly indicative of the health of the system: phytoplankton chlorophyll (CHL), suspended particulate matter (SPM), and colored dissolved organic matter (CDOM). Because of their proximity to land and influence of river flow, concentrations of CDOM and SPM may vary independently of CHL, posing special problems for interpretation of remotely sensed signals. In the Rhode River CISNet project, we have developed a system for continuously monitoring spectral absorption and scattering coefficients utilizing a commercially available absorption/transmittance meter. A mathematical procedure for determining the concentrations of light absorbing materials has been developed, and shows 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, and demonstrated that attenuation was dominated by chlorophyll in the early stages of the bloom, and by detritus at the termination of the bloom. The measurement and mathematical analysis procedures have recently been extended to mapping of surface optical properties, as well as the concentrations of optical components. Such measurements should help refine maps of water quality fields obtained by aircraft remote sensing, especially at times when signals are saturating due to high chlorophyll concentrations, or are below detection due to interfering concentrations of CDOM or SPM.

Keywords: Estuaries, optical properties, remote sensing, Rhode River, Chesapeake Bay

A PROTOTYPE SHELF-WIDE OBSERVING SYSTEM

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The Rutgers University Institute of Marine and Coastal Sciences (IMCS) currently operates the Long-term Ecosystem Observatory (LEO) offshore Tuckerton, New Jersey. Satellite and shore-based remote sensing systems and subsurface cabled observatories are capable of providing year-round data within an approximately 30 km x 30 km research space. In an annual series of summer Coastal Predictive Skill Experiments (CPSEs), the LEO system is enhanced with numerous adaptive sampling platforms that include ships, aircraft and autonomous underwater vehicles operating within the well-sampled environment. Objectives of the July 2000 CPSE included biological adaptive sampling of kilometer scale episodic features guided by ocean forecasts and real-time physical data. Over 190 scientists and researchers from 30 academic, government and industrial partners participated. The website for accessing the real-time datasets averaged over 50,000 hits per day, the majority coming from the general public.

Larger regional-scale coastal ocean observatories are being proposed or constructed on continental shelves throughout the United States. The Institute of Marine and Coastal Sciences' (IMCS) Coastal Ocean Observation Lab (COOL) is constructing a regional observatory to characterize the physical forcing of continental shelf primary productivity. Observatory components tested at LEO in 2000 will be used to expand the New Jersey Shelf Observing System (NJSOS) to the approximately 300 km x 300 km scale of the New York Bight. Backbone components of the regional NJSOS system include new long-range and bistatic CODAR HF-Radar systems, local access to the direct-broadcast data from the growing international constellation of ocean color satellites, and long-duration autonomous underwater gliders equipped with physical/bio-optical sensors. The three backbone components will be operated from a regional control room specifically designed for collaborative research and teaching. Data will be shared with other researchers and the general public via the World Wide Web and the Java-based Rutgers Ocean Data Access Network (RODAN). The lower operating expenses of the remote and autonomous systems make NJSOS a viable prototype for a national network of linked regional observatories.

Key Words: Ocean Observatory, HF Radar, Ocean Color, Autonomous Vehicles

Coastal Indicators of Integrity and Sustainability (STAR Estuarine and Great Lakes Programs)

DEVELOPMENT OF ENVIRONMENTAL INDICATORS OF CONDITION, INTEGRITY, AND SUSTAINABILITY IN THE COASTAL REGIONS OF THE US GREAT LAKES BASIN

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We have initiated a cooperative project consisting of seven universities and US EPA ORD, primarily the Mid-continent Ecology Division, to identify, evaluate, and recommend a portfolio of multi-scaled environmental indicators relevant to the coastal regions of the US Great Lakes basin. Our major question is "what environmental indicators will most efficiently, economically, and effectively measure the condition, integrity, and long-term sustainability of the basin." We will test the indicators with a combination of existing data, a pilot study, and a more comprehensive field study in years 2 and 3 that are linked with stressors of the basin. Year 4 will be dedicated to analysis and recommendation of a suite of hierarchically structured indicators. Our research plan uses EPA's ecological risk assessment paradigm to 1) illustrate the development of indicators, 2) test cause and effect between stressors and endpoints, and 3) provide essential linkages with EPA initiatives and programs. Indicators are divided into pressure (stressors) and state indicators (individual, population, community, and landscape-level endpoints or responses to the stressors). Major stressors include land use change, climate change, point and non-point discharges, exotic species, atmospheric deposition, and hydrological modifications. State indicators focus on biotic populations and communities (amphibian, bird, diatoms, fish, macroinvertebrates, and aquatic plants), land cover, and water quality (contaminants, nutrients). Field sampling will employ a random stratified design using ecological provinces, watersheds, shoreline reaches, and ecosystem types as the basis for stratification. The Great Lakes Sea Grant network will communicate and integrate the results of the project with the Great Lakes community.

Keywords: Great Lakes, monitoring, indicators, risk assessment, stressor, ecological effects, animal, plant, diatoms, toxics

SYNOPSIS OF THE WESTERN CENTER FOR ESTUARINE ECOSYSTEM INDICATOR RESEARCH (CEEIR) PROGRAM AND OBJECTIVES

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The *first and overarching objective* is to develop indicators of wetland ecosystem health that are both simple aggregations of data as well as more complex expressions of overall ecosystem health. The *second objective* is to develop indicators of integrity for specific plant, fish, and invertebrate populations within wetlands. The *third objective* is to develop indicators of toxicant-induced stress and bioavailability for wetland biota. Integration among proposals is achieved using: 1) integrative laboratory experiments to determine bioavailability of toxicants in tandem with biomarker responses, 2) field sampling at common sites ranging from northern California to Mexico, 3) model species including wetland plants, gammarid amphipods, and a species of goby, 4) overlapping experimental and sampling designs that permit tests of interdisciplinary hypotheses, 5) common data management and GIS capabilities, which will be used to integrate ongoing monitoring studies with our own census data, and 6) modelling and statistical studies that compare indicator ranking procedures to model projections. The extensive integration among proposals enables cost-effective yet rigorous development of indicators on multiple scales across a broad geographic region with characterization of both ecosystem health and stressors. The five proposals include: The Ecosystem Indicators Component (EIC), the Biological Responses to Contaminants Component (BRCC), the Biogeochemistry and Bioavailability Component (BBC), the Remote Sensing Component (RSC) and the "Center Proposal". We will address urgent problems such as: wetland degradation and fish population declines in San Francisco Bay, ecological assessment of mercury contamination in Tomales Bay, and metals and pesticide contamination of northern and southern California watersheds.

Keywords: watersheds, estuary, ecological effects, bioavailability, ecosystem indicators, aquatic, integrated assessment, EPA Region IX

ATLANTIC COAST ENVIRONMENTAL INDICATORS CONSORTIUM (ACE INC)

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We are developing integrative indicators of ecological condition, integrity, and sustainability across four representative estuarine systems on the US Atlantic Coast. Included are two large estuarine complexes, Chesapeake Bay (MD/VA) and Albemarle-Pamlico Sound, NC (EPA CISNet sites), and two small estuaries, Parker River (Plum Island Ecosystems NSF-LTER), MA, and North Inlet, SC (EPA CISNet). These sites span the major east coast biogeographic provinces, range in primary production resource base (salt marsh, seagrass, planktonic), vary in water residence times (few days to 1 year), and contain pristine and impacted regions, which will facilitate comparative assessments of ecosystem responses to perturbations. We will 1) enhance existing data with remotely sensed, time-series information on key variables; (2) synthesize detailed knowledge of these well-studied systems to develop candidate indicators; (3) test these indicators to gauge ecosystem health and detect trends resulting from natural variability and anthropogenic stresses. We will develop indicators of 1) microalgal and macrophyte functional groups controlling primary production, 2) plankton and fish community structure and function, that relate to trophic transfer and sustainability and 3) intertidal marsh response to sea level rise. These indicators form the backbone of ecosystem, regional and national-level water quality, habitat assessment and living resources monitoring and modeling efforts, and will serve to calibrate and ground truth remote sensing of estuarine and coastal resources. Our aim is to produce accurate representations of ecosystem function and health, to detect trends in health, and to use these indicators to predict effects of human actions vs. natural variability across estuarine ecosystems regionally and nationally.

DEVELOPMENT, TESTING, AND APPLICATION OF ECOLOGICAL AND SOCIOECONOMIC INDICATORS FOR INTEGRATED ASSESSMENT OF AQUATIC ECOSYSTEMS OF THE ATLANTIC SLOPE IN THE MID-ATLANTIC STATES

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Coasts, estuaries, rivers, streams, lakes, and wetlands must be viewed as one integrated system. Understanding and documenting the linkages between upstream watersheds and downstream estuaries is critical to the success of our approach, and to the protection, management, and restoration of receiving rivers, estuaries, and bays. The study area is the mid-Atlantic Slope encompassing three major drainage basins extending from the Appalachian Mountains to the Atlantic Ocean; Delaware, Susquehanna-Chesapeake, and Ablemarle-Pamlico basins. Our team, the Atlantic Slope Consortium, will develop and test a set of indicators to be used for integrated assessments of the condition, health and sustainability of aquatic ecosystems. Indicators will based on ecological and socioeconomic information compiled at the scale of estuarine segments and small watersheds. The three working groups (estuary, watershed, socioeconomic) will examine indicators such as: optical properties of estuarine waters, habitat suitability models, submersed aquatic vegetation, finfish and shellfish closures, condition of tidal and non-tidal wetlands, bird communities, nutrient and sediment discharges, income from resource-based activities, health status, education level, membership in watershed associations, and expenditures on environmental protection, water supplies, and wastewater treatment. Managers will be intimately involved in our process of indicator selection and development through cooperator workshops. A suite of tested ecological and socioeconomic indicators that clearly relate stressors, sources, and solutions between upstream watersheds and downstream estuaries will be delivered. This study will address the administrative, organizational, and perceptual obstacles and limitations to adopting and implementing the recommended indicators in a monitoring system for coastal ecosystems. We will make publicly available extensive spatial data sets and graphical displays of ecological and socioeconomic information for this region.

Keywords: ecological indicators, integrated assessment, aquatic ecosystem, wetland, stream, estuary, coastal, biological integrity, landscape ecology, socioeconomic, Mid-Atlantic, EMAP

Coastal Monitoring Programs: Results from Successful Partnerships III

THE REGIONAL MONITORING PROGRAM FOR TRACE SUBSTANCES – EFFECTIVE APPLICATION OF SCIENTIFIC INFORMATION IN MULTI-AGENCY DECISION-MAKING

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The San Francisco Estuary Regional Monitoring for Trace Substances is an innovative partnership between a state agency, 74 waste discharge permit holders, and an independent scientific institute. The approximately $3M annual funding pool has produced scientific results that have made the regulatory system increasingly responsive to emerging management needs, particularly with regard to the development of total maximum daily loads and ecosystem impairment assessment. Through multi-agency partnerships within and outside the RMP institutional structure, major information gaps for several pollutants of concern have been narrowed, resulting in a successful consensus-based regulatory approach to managing copper and nickel mass inputs into the Estuary. Additionally, monitoring data, accompanied by short-term research efforts by collaborating agencies and academic institutions helped in prioritizing the most cost-effective control and remediation options for various bioaccumulative substances and raised the visibility of one of the most controversial pollution issues in the Estuary – pesticide runoff from agricultural and urban areas. One of the most important contributions of this collaborative monitoring program is the deliberate and systematic adjustment of management and research questions that serve to influence and add relevance to the overall research agenda related to San Francisco Estuary ecosystem assessment.

Key Words: Monitoring, TMDL, Impairment Assessment, Adjustment of Management and Research Questions

INITIAL RESULTS FROM DEPLOYMENT OF A COASTAL MONITORING BUOY --HOW COLLABORATIONS THROUGH CISNET ARE LEADING TO IMPROVED MONITORING AND RESEARCH IN PUGET SOUND

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Waterbodies within Puget Sound are diverse, ranging from deep fjord-like basins to constricted shallow bays. In addition, water quality indicators are extremely dynamic, responding to the strong tidal and seasonal forcing of the region. Such attributes make monitoring a particular challenge. Rapid growth projections for the Puget Sound area dictate a need for better understanding of ecosystem susceptibility to human impacts. Washington State's long-term monitoring program has identified several sites potentially sensitive to eutrophication, based on indicators such as persistent stratification, low oxygen, and nutrient concentrations. However, carbon, oxygen and nutrient dynamics of this region, and in particular phytoplankton growth and abundance, are still poorly understood.

A partnership between state (Washington State Department of Ecology) and academic (University of Washington) scientists is being supported by EPA/NOAA/NASA funding as part of the Coastal Intensive Site Network program to establish an intensively monitored site in southern Puget Sound. The goal of the project is to address questions relating to temporal and spatial scales of variability in ecosystem indicators, using a combination of a profiling mooring and remote sensing. One objective is to use high temporal resolution measurements from the mooring to enhance our understanding of ecosystem variability and status that is necessary to document long-term change. The profiling mooring can resolve hydrography, oxygen, nutrient, optical, and biological variables over the 50-m water column multiple times each day. A second objective is to conduct bio-optical measurements for the development of remote-sensing indicators for extrapolation of mooring results to larger spatial scales. This collaborative strategy has increased the efficacy of the monitoring program and focuses new analytical technologies on a regional concern.

Keywords: Partnerships, eutrophication, monitoring, water quality

GREAT LAKES MONITORING RESULTS – A HISTORY PERSPECTIVE AND COMPARISON OF PROBABILITY BASED AND DETERMINISTIC SAMPLING GRIDS

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The Great Lakes may be viewed as a coastal environment. Predominantly counter-clockwise currents move along the shores of the lakes, affected by the same meteorological and physical forces as the coastal ocean. Average depth of the lakes ranges from 19 to 147 meters. The U.S. EPA, Great Lakes National Program Office has monitored the open waters of the lakes, annually, since 1983. Trends in nutrient concentrations and changes in biological communities have been tracked. Monitoring results show that attempts to decrease nutrient loads to decelerate eutrophication have, on the whole, succeeded. Recent exotic species invasions are drastically changing the ecosystem. Monitoring continues, but is changing to be responsive to the needs of users of the information, while maintaining a long-term perspective. The sampling network was designed using a deterministic approach based on extensive sampling. A comparison, in Lake Michigan, of a statistically based (EMAP) grid and traditional station array, shows the similarity of results from the two sampling strategies.

BI-NATIONAL ASSESSMENT OF THE GREAT LAKES - A LOOK AT SOLEC

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Many administrative jurisdictions have authority over parts of the Great Lakes, sometimes with competing purposes as well as governance at differing scales of time and space. The demand for high quality information that is relevant to environmental managers, however, is forcing environmental and natural resource agencies with limited budgets to be cooperative and selective in the collection, analysis and reporting of data. The State of the Lakes Ecosystem Conferences (SOLEC) were begun in 1994 in response to reporting requirements of the Great Lakes Water Quality Agreement between Canada and the U.S. The biennial conferences are to provide independent, science-based reporting on the state of health of the Great Lakes ecosystem components. A suite of indicators necessary and sufficient to assess Great Lakes ecosystem status was introduced in 1998, and assessments based on a subset of the indicators were presented in 2000. Because SOLEC is a multi-agency, multi-jurisdictional reporting venue, the SOLEC indicators require acceptance by a broad spectrum of stakeholders in the Great Lakes basin. The SOLEC process recognizes that individual programs and jurisdictions need to maintain unique indicators. However, the SOLEC indicators list is expected to provide the basis for government agencies and other organizations to more effectively collaborate and allocate resources to data collection, evaluation and reporting on the state of the Great Lakes ecosystem.

Keywords: Great Lakes, indicators, SOLEC

MONITORING CONTAMINANT EXPOSURE AND FISH HEALTH IN PUGET SOUND, WA: A SUCCESSFUL STATE/FEDERAL PARTNERSHIP

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Impaired health of bottom fish in Puget Sound was first noted in the mid-1970s by scientists from a federal research facility in Seattle (Northwest Fisheries Sciences Center). English sole (Pleuronectes vetulus) in urbanized waterways were found to have increased prevalences of several liver diseases, including cancer. Subsequent studies by this laboratory into the 1980's established the causal link between polycyclic aromatic hydrocarbons in sediments and these diseases. The findings from these efforts led to the incorporation of liver disease in fish as a monitoring tool nationally under NOAA's National Status and Trends Program (1984-1994) and locally under the Puget Sound Ambient Monitoring Program (1989-ongoing). As the research interests of the federal lab began to turn to other endpoints, such as reproductive and immune function, in the 1990s, the state agency (Washington Department of Fish and Wildlife) continued to monitor toxicopathic fish disease as an indicator of the state of Puget Sound. Thus, a local, and at first mostly informal, partnership began between state and federal scientists. From modest beginnings, and through close communication and continued collaboration in the collection and analyses of samples, this effort has become a model for technology and information transfer between agencies, which leads to continuation of monitoring programs despite changing agency priorities. Collectively, we have broadened the geographic coverage of contaminant studies in Puget Sound, increased the number of fish species monitored, and initiated pilot studies (e.g., endocrine disruption in marine fish). This federal-state partnership could serve as a model for development of broad-based regional approaches to monitoring programs.

CONSERVATION AND MANAGEMENT APPLICATIONS OF THE REEF VOLUNTEER FISH MONITORING PROGRAM – THE SUCCESS OF PARTNERSHIPS

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The REEF Fish Survey Project is a volunteer fish monitoring program developed by the Reef Environmental Education Foundation (REEF). REEF volunteers collect fish distribution and abundance data using a standardized visual method during regular diving and snorkeling activities. Survey data are recorded on preprinted data sheets that are returned to REEF and optically digitized. These data are housed in a database that is publicly accessible on REEF's Website (http://www.reef.org). Since its inception in 1993 the REEF program has generated over 30,000 surveys in the Project region, which includes all coastal waters of North America. Through partnerships with federal and state agencies, scientists, conservation organizations, and private institutions, the Fish Survey Project has been incorporated into existing monitoring programs. The educational value and increased stewardship that results from volunteer data collection has also been used by REEF's partners. In addition, management and conservation applications for the REEF data have been identified. Current applications include an evaluation of fish/habitat interactions in the Florida Keys National Marine Sanctuary, the development of a multi-species trend analysis method to identify sites of management concern, assessment of the current distribution and status of protected species, status reports on fish assemblages of marine parks, and the evaluation of no-take zones in the Florida Keys. REEF's collaboration with a variety of partners, combined with REEF's database management system and the Fish Survey Project's standardized census method, has resulted in a successful citizen science monitoring program.

Key Words: marine fish, volunteer monitoring, conservation

Spatial Tools for Coastal Assessment and Mapping

SPATIAL ANALYSIS OF GRAIN SIZE IN SANTA MONICA BAY

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Maps are useful scientific tools for presenting environmental information, but the statistical techniques necessary to prepare scientifically rigorous maps have primarily focused on terrestrial habitats. This study compares three popular techniques (triangulation, kriging, and co-kriging) to map sediment grain size in Santa Monica Bay, California. Two grain size data sets, one collected in 1994 (79 sites) and one collected in 1997 and 1998 (149 sites) were used for model development. A bathymetric data set collected in 1997 was used as a model covariate. A third grain size data set (40 sites) collected in 1996 from independent sites was used for model evaluation. Predictions were compared to validation data by average difference, prediction mean square error (PMSE), and a goodness-of-prediction measure, G. The average difference between prediction and truth was similar for all methods, but the PMSE for triangulation was more than twice that for kriging or co-kriging, which were similar. The G measure also shows triangulation to be a far worse predictor than kriging and co-kriging. Small-scale differences were observed between kriging and co-kriging at steep depth contours, where co-kriging predicted values commensurate with the expected depth-defined grain size.

Keywords: Spatial modeling, kriging, co-kriging, interpolation, marine sediment grain size

GEOSTATISTICAL ISSUES FOR MODELING MERCURY CONTAMINATION IN THE FLORIDA EVERGLADES

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Mercury contamination of soils poses a significant health hazard for humans and animals exploiting fish in the marsh waters of the Florida Everglades. The concentration of mercury depends on the bulk density of the soil. In addition, methyl and ethyl mercury concentrations are left censored at the minimum detection level of instruments used to assay soil samples. A hierarchical model is considered for the concentrations of methyl and ethyl mercury together with the bulk density of soils. Conditional on bulk density, observed methyl and ethyl mercury concentrations are modeled as a partial realization of a truncated log-Gaussian random field. Under this model, the true log methyl and ethyl mercury concentrations are written as linear functions of bulk density plus a spatially correlated errors, and bulk density is modeled as a linear function of the spatial coordinates plus another spatially correlated error. Assuming that the error terms are independent, the log likelihood can be partitioned into separate terms for estimating the parameters of the two components of the model. A multivariate version of the Robbins-Monro algorithm tied to importance sampling is used to estimate model parameters. An importance sampling algorithm is used to obtain cokriging predictors of mercury concentrations at unsampled sites. The proposed methods are illustrated using data from the South Florida Ecosystem Assessment Project, a Regional Environmental Monitoring and Assessment Program (REMAP) sponsored by the Environmental Protection Agency.

SPATIALLY REFERENCED REGRESSION MODELING OF NUTRIENT LOADING IN THE CHESAPEAKE BAY WATERSHED

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To support efforts to restore water quality in the Chesapeake Bay, the U.S. Geological Survey (USGS) has developed a set of spatially detailed regression models that relate nutrient sources and land-surface characteristics to stream nutrient loads. The methodology used is referred to as SPAtially Referenced Regressions On Watershed attributes (SPARROW). SPARROW is based on a spatially detailed hydrologic network that consists of a digital stream network and drainage boundaries that define the watersheds for each stream reach. For the Chesapeake Bay watershed, the network includes 2,249 stream segments with associated drainages that average approximately 28.5 square miles in area. To date, total nitrogen and total phosphorus models have been developed on the basis of data for the years 1987 and 1992. The 1992 models include several enhancements that were designed to improve statistical power and spatial detail. For both sets of models, significant relations between the spatial distribution of stream nutrient loads and that of point sources, urban area, agricultural sources, and atmospheric deposition were identified. Instream loss rates were significant in all of the models and tended to be greatest in the smallest streams. Thus, the areas with the greatest yields delivered to the Bay include those that are close to the Bay and have short travel times, as well as those that drain to large rivers and have small instream loss rates. The SPARROW models are currently being used to identify areas of high loading, identify the sources of those loads, and target areas for management activities.

Keywords: water quality, nutrients, stream loading, Chesapeake Bay, GIS, modeling

A HYDROLOGIC NETWORK TO SUPPORT SPATIALLY REFERENCED REGRESSION MODELING IN THE CHESAPEAKE BAY WATERSHED

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The U.S. Geological Survey (USGS) has developed a methodology for statistically relating nutrient sources and land-surface characteristics to nutrient loads of streams. The methodology is referred to as SPAtially Referenced Regressions On Watershed attributes (SPARROW), and relates measured stream nutrient loads to nutrient sources in the watershed through the use of nonlinear statistical regression models. A spatially detailed digital hydrologic network of attributed stream reaches and their associated watersheds supports the models. This network serves as the primary framework for spatially referencing nutrient sources and land-surface characteristics used in the models. For application in the Chesapeake Bay watershed, a hydrologic network was derived from Digital Elevation Models (DEM) and an existing 1:500,000-scale digital stream network attributed with streamflow characteristics. New stream reaches were defined through a flow accumulation algorithm and the DEM. Where that algorithm failed to produce satisfactory stream reaches, sections of the 1:100,000-scale national hydrography data set were inserted. Stream-reach attributes such as mean discharge and travel-time were transferred from the existing 1:500,000-scale data on a reach-by-reach basis. To complete the network, watersheds were generated for each reach using flow direction from the DEM. This hydrologic network improves upon existing digital stream data by increasing the level of spatial detail and providing consistency between the reach locations and topographic features. The hydrologic network also aids in illustrating the spatial patterns of predicted nutrient yields and sources contributed locally to each stream, and the percentages of nutrient load that reach Chesapeake Bay.

Keywords: SPARROW, regression, Chesapeake Bay, nutrient, loads, modeling, reach, stream, RF1, hydrography, watersheds

SUBMERSED AQUATIC VEGETATION MAPPING USING HYPERSPECTRAL IMAGERY

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Submersed aquatic vegetation (SAV) beds are important resources for aquatic life and wildfowl in the Potomac River and Chesapeake Bay region. SAV habitat is threatened in part by nitrogen loadings from human activities. Monitoring and assessing this resource using field based sampling and mapping using aerial photography is time consuming and costly. The use of airborne hyperspectral remote sensing imagery for automated mapping was investigated for near to real-time resource assessment and monitoring. Field surveys for several pilot sites determined SAV species, density, and distribution as well as water quality and optical parameters. Airborne hyperspectral imagery, together with in-situ spectral reflectance measurements using a field spectrometer, were obtained for the pilot sites in spring and early fall. A spectral library database containing selected ground-based and airborne sensor spectra was developed for use in image processing. The goal of the spectral database is to automate the image processing of hyperspectral imagery for potential real-time material identification and mapping. Field based spectra were compared to the airborne imagery using the database to identify and map several species of SAV, suspended sediment concentrations, chlorophyll, and wetland vegetation. The resulting imagery derived vegetation maps were assessed for overall accuracy using aerial photography and field based sampling. Ultimately, the species data could be used to study SAV population dynamics and relationships between environmental variables and invasive and native species of SAV. The algorithms and databases developed in this study will be useful with the current and forthcoming space-based hyperspectral remote sensing systems.

FLORIDA BLUEWAYS: USING SPATIAL TECHNIQUES TO INTEGRATE ECOLOGICAL, HUMAN-USE AND MANAGEMENT INFORMATION TO ENABLE ECOSYSTEM SCALE MANAGEMENT OF FLORIDA'S COASTAL RESOURCES

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Coastal resource managers need to analyze and weigh information about resource users and management actions in addition to ecological data in order to make informed decisions. Florida BlueWays is a new program emerging from a strong partnership between the Florida Coastal Management Program and the Florida Fish & Wildlife Commission's Florida Marine Research Institute. It is designed to ensure that managers can access complete information covering these three areas – ecological conditions, human uses, and management activities – in an integrated way so that management can be more effective, comprehensive, and streamlined.

This partnership and the BlueWays development process have been in place for two years.

FCMP and FMRI are constructing a mapping-based information management tool. The core of BlueWays is a Geographic Information System (GIS) built around three environmental characterizations:

- Ecological: describes physical and biological characteristics of the management region
- Human Use: categorizes and maps resource uses
- Management: depicts all the management actions taking place. Including efforts in all levels of government and activities outside government like volunteerism and private research efforts

These will be incorporated into a suite of easy-to-use tools that will allow resource managers to examine natural-science data for an area while simultaneously considering existing resource uses and management efforts. BlueWays will allow managers to follow a path from identifying areas of particular ecological importance, to investigating whether there are potentially damaging human uses in these areas, to identifying regulations and enforcement actions currently in effect. There are myriad additional potential applications as well.

The history, current status and future goals of BlueWays will be discussed.

Coastal TMDL Development and Implementation

NEWPORT BAY, CALIFORIA NUTRIENT TMDL

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Newport Bay, in Orange County, was placed on the 303(d) list by the State of California due to impairment by nutrients, bacteria, sediment, and toxics. A Consent Order was signed mandating the development of TMDLs for these parameters over a very aggressive time scale. This talk focuses on the development of the nutrient TMDL. Numeric water quality standards do not exist for nutrients in the Bay, and the primary symptom of the nutrient impairment was dense mats of macroalgae. TMDL development, especially over the mandated time frame, faced many challenges:

- Development of a quantitative water quality objective for the endpoint of concern (macroalgae)
- Development of a water quality model that could predict the relationship between nutrient loads and resulting macroalgal density
- Freshwater stratification that results in short residence nutrient times in the Bay during winter storm events
- Conflicting data regarding whether nitrogen or phosphorus was the limiting nutrient
- Active stakeholder involvement in the TMDL development from parties with diametrically opposed viewpoints

A TMDL was successfully developed and approved by EPA Region IX in the required time frame. This talk will present how the TMDL was developed, how stakeholder involvement was incorporated in the process and the ongoing efforts to refine and implement the TMDL.

Keywords: TMDL, TMDL development, Newport Bay, TMDL implementation, stakeholder involvement

TRANSITIONING FROM A VOLUNTEER NUTRIENT REDUCTION PROGRAM TO A REGULATORY TMDL: EXPERIENCES FROM TAMPA BAY, FLORIDA

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Participants in the Tampa Bay Estuary Program have agreed to adopt nitrogen loading targets for Tampa Bay based on the water quality and related light requirements of underwater seagrasses. Based on empirical regression-based methods and mechanistic modeling results, it appears that light levels can be maintained at necessary levels by "holding the line" at 1992-1994 nitrogen loadings. However, this goal may be difficult to achieve given the 20% increase in the watershed's human population and associated 7% increase in nitrogen loading that are projected to occur over the next 20 years.

To address the long-term management of nitrogen sources, a Nitrogen Management Consortium of local electric utilities, industries ,agricultural interests, local governments and regulatory agency representatives voluntarily developed a Consortium Action Plan in 1997 to address the target load reduction needed to "hold the line" at 1992-1994 levels. As of 2000, implemented projects collated in the Consortium Action Plan met and exceeded the agreed-upon nitrogen loading reduction goal.

In 1998, EPA Region 4 approved the technical basis and implementation strategy developed by the Tampa Bay Nitrogen Management Consortium as the TMDL for nitrogen for Tampa Bay. An integral element of this approach is the EMAP-based water quality monitoring program designed to provide quantifiable status of bay water quality condition. The transition from a voluntary public/private nutrient reduction strategy, in which the partners agree to collectively meet load reduction goals, to a regulatory TMDL program includes technical, policy and philosophical elements currently being addressed by the Tampa Bay partners and EPA.

USE OF INTEGRATED MONITORING DATA TO ASSIST IN TMDL DEVELOPMENT FOR URBAN STORMWATER

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Stormwater runoff from urbanized watersheds in southern California is a major source of pollutants to receiving water bodies and a prime target of many TMDLs. However, little work has been accomplished to assess the magnitude of toxicity, identify toxicants of concern, and impacts of runoff discharges in receiving water bodies. Development of effective TMDLs is often hampered by a lack of adequate information about the magnitude, cause, and extent of water quality impairments for the area. Moreover, virtually no information exists as to runoff impacts on marine habitats, where most effects are expected to occur in this region. This study was designed to determine the magnitude of toxicity in a stormwater discharge to a marine species (purple sea urchin, *Strongylocentrotus purpuratus*), measure the spatial extent of the toxic portion of the runoff plume in San Diego Bay, and identify the toxicants of concern. Six storms were sampled between the 1998/99 and 1999/2000 water years. Every runoff sample was toxic; the NOECs ranged from 3% to 12% runoff. Plume mapping surveys in San Diego Bay showed that runoff formed thin lenses approximately one to three meters thick, but they extended across the entire Bay. Approximately one-quarter to one third of the plume extent was estimated to be toxic. Trace metals, primarily zinc, were identified as the toxic constituents responsible for effects in both the discharge and plume samples from the receiving waters. Management actions following this study include a total maximum daily load (TMDL) for trace metals in this watershed.

Keywords: Stormwater, toxicity, TIE, San Diego

AN INTEGRATED COASTAL-WATERSHED MONITORING FRAMEWORK FOR ASSESSMENT, DIAGNOSIS OF BIOLOGICAL IMPAIRMENT, AND PRIORITIZATION OF WATERSHED RESTORATIONS: GREAT LAKES PILOT PROJECTS

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An approach for watershed classification in support of assessments, diagnosis of biological impairment, and prioritization of watershed restorations has been tested in coastal watersheds surrounding the western arm of Lake Superior and is currently being assessed for a series of 22 coastal wetland watersheds surrounding Lake Michigan. Lake Superior tributaries were stratified by hydrogeomorphic region (USFS ecological units), then by two watershed characteristics related to hydrologic thresholds: watershed storage (lake + wetland area/watershed area) and forest fragmentation. The ecoregion scale was not fine enough to establish reference condition or driving factors influencing water quality or community composition; however stratification by ecological unit, storage and fragmentation explained a significant amount of variation in water quality and periphyton, macroinvertebrate, and fish communities. In addition to watershed classes, diatom communities were influenced by habitat features (flow, complexity, conductivity, shading, bank erosion), as well as macroinvertebrate abundance and community structure. Macroinvertebrate communities in both ecological units responded primarily to substrate, hydrology, and temperature differences among the diverse stream types. Fish communities clearly responded to differences in thermal regime which were correlated with both forest fragmentation and watershed storage. This approach is being extended to Lake Michigan coastal wetlands selected through a classic EMAP design (stratified by ecoregion and size class) with assessment of alternate approaches to calculate watershed indices of flashiness in areas of mixed land-use. Watershed flashiness will be related to indicators of sediment and nutrient exposure, and to indices of biotic integrity for vegetation, macroinvertebrate, and fish communities in coastal wetlands.

A GREAT LAKES APPROACH TO DEVELOPMENT OF TMDLS – THE LAKE MICHIGAN MASS BALANCE STUDY

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The Great Lakes may be viewed as a bounded coastal environment. The lakes receive chemical input from the atmosphere, as well as a large number of tributaries that flow through multiple jurisdictions. A mass balance approach of monitoring and modeling, leading to load reduction, was established in the 1970's to deal with eutrophication. The results of the effort can be considered a TMDL, particularly for Lake Erie. Ecological and regulatory concerns in the Great Lakes have moved away from nutrient enrichment problems, with bioaccumulative contaminants being the main focus. An extension of the mass balance approach from nutrients, to other contaminants, has led to two studies, the Green Bay Mass Balance Study and the Lake Michigan Mass Balance Study. Models developed for these studies, provide the tools to determine the impact of load reduction on the concentrations of persistent bioaccumulative contaminants in all media. The main emphasis is on top predator fish, which are under fish consumption advisories for PCBs. We view the application of these models as an advance in developing TMDLs for the Great Lakes and potentially for other large water bodies.

ACCEPTING SOUTH CAROLINA'S "0.1 RULE"- A TMDL CASE STUDY OF LARGE REDUCTIONS IN PERMITTED LOADING WITHOUT LITIGATION

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The Grand Strand is a rapidly growing retirement and resort area on the northeastern coast of South Carolina. Under the State's water-quality standards, permitted water- reclamation facilities cannot have a cumulative impact greater than 0.1 milligrams per liter of dissolved oxygen ("0.1 Rule") to the receiving waters. To simulate the tidal and water-quality dynamics of the receiving streams, the Branched Lagrangian Transport Model, developed by the U.S. Geological Survey, was calibrated and validated for the tidally influenced portions of the Pee Dee River, Waccamaw River, Bull Creek, and the Atlantic Intracoastal Waterway.

Application of the model to calculate the Total Maximum Daily Load (TMDL) consisted of selecting appropriate initial and boundary conditions for streamflow, water-quality, and meteorological conditions that are protective of aquatic resources without being overly restrictive to permitted dischargers. The selection of appropriate conditions was critical in determining the assimilative capacity of the receiving stream and, therefore, the TMDL. A working group was formed to provide technical input and review of the model application. The group consisted of a water-quality modeler from the South Carolina Department of Health and Environmental Control, a hydrologist from the U.S. Geological Survey representing the model developers, and a water-resources engineer representing a consortium of water utilities.

Through a collaborative process, members of the technical group proactively provided input to address various technical aspects of the model to the TMDL application. Based on the results of the model, environmental regulators and permits holders were able to reach a consensus on the technical soundness of the TMDL which called for a 60-percent reduction in the permitted wastewater loads to the Waccamaw River and Atlantic Intracoastal Waterway.

Keywords: assimilative capacity, TMDL, water-quality model, boundary conditions, Pee Dee River, Waccamaw River, Atlantic Intracoastal Waterway

Microbial Genetic Indicators: Community Diversity, Trophic Interactions and Designated Use Attainment

MOLECULAR APPROACHES TO MICROBIOLOGICAL MONITORING

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Molecular methods are useful both to monitor natural communities of bacteria, and to track specific bacterial markers in complex environments. Length-heterogeneity polymerase chain reaction (LH-PCR) of 16S rDNAs discriminates among numerically dominant 16S rRNA genes based on length polymorphisms of their PCR products. With this method, we compared microbial communities in Tillamook Bay, OR, to evaluate spatial and temporal differences. Using multivariate statistics, we correlated these differences to changes in environmental conditions. We have begun a study to test whether LH-PCR profiles correlate with standard bacteriological measures (heterotrophic plate counts, coliform measures), and with EMAP measures of ecological integrity. Using the same approach, we developed an alternative indicator that distinguishes the source of fecal pollution in water. We amplify 16S rRNA gene fragments from the fecal anaerobic genus *Bacteroides* with specific primers. Because *Bacteroides* normally resides in gut habitats, its presence in water indicates fecal pollution. Molecular detection circumvents the complexities of growing anaerobic bacteria. We identified *Bacteroides* LH-PCR and terminal restriction fragment length polymorphism (T-RFLP) ribosomal DNA markers unique to either cow or human feces. The same unique fecal markers were recovered from polluted natural waters. Marker sequences were used to design specific PCR primers that reliably distinguish human from ruminant sources of fecal contamination; we are designing primers for more species. This approach is more sensitive than fecal coliform assays, is comparable in complexity to standard food safety and public health diagnostic tests, and lends itself to automation and high-throughput. Thus molecular genetic markers hold promise for monitoring bacterial communities and water quality.

Key words: Microbiological monitoring, fecal contamination, source discrimination, LH-PCR, bacterial communities, *Bacteroides*, molecular markers

CHARACTERIZATION OF MICROBIAL COMMUNITIES FROM COASTAL WATERS

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For a number of years our group has used molecular methods, including DNA probes, to identify and enumerate pathogenic *Vibrio* species in the Chesapeake Bay and other coastal waters; our data indicated that *V. vulnificus* constituted approximately 8% of the total culturable heterotrophic bacteria in the Bay, with clear seasonal fluctuations in bacterial number linked with water temperature. More recently, our work has expanded to include characterization of total microbial communities from the Bay; development of microarrays that identify and quantify the diversity of those communities; and observation of temporal changes in those communities. To identify members of the microbial community, we amplified (using universal primers) the 16s rDNA gene from community DNA isolated from a biofilm sample collected from the Chesapeake Bay in February. The resultant 75 sequences were 95% or more similar to 7 species including two recently described *Shewanella* species, *baltica* and *frigidimarina*, that to our knowledge have not been previously isolated from the Chesapeake Bay. Based on our 16s findings, we are developing microarrays to detect these and other microbial species that may be present in these estuarine communities. The microarrays will detect each species using four distinct loci, with the multiple loci serving as an internal control. The accuracy of identification and quantification by the microarray will be measured using culturable bacteria such as *Aeromonas* species, *E. coli*, and *Vibrio vulnificus* as sentinels. With these techniques it should be possible to determine the annual fluctuations of bacterial species (both culturable and non-culturable, pathogenic and non-pathogenic) in the Bay, data which are potentially applicable to understanding patterns of environmental change; assessing the “health” of the Bay; and evaluating the risk of human illness associated with exposure to and ingestion of water and shellfish.

MOLECULAR METHODS FOR ENVIRONMENTAL MONITORING: NEW TOOLS FOR OLD PROBLEMS

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A worldwide increase in the frequency and distribution of harmful algal bloom (HAB) events has been well documented. Many of these blooms are associated with adverse human health effects, including gastrointestinal, respiratory, and cognitive problems. Due to the significance and persistence of these blooms, intensive monitoring efforts have been initiated. These efforts are important for identifying loci of species persistence and for understanding environmental change that may be conducive to blooms. Development of techniques for identification of target species has quickly evolved to allow for more rapid and specific detection of these organisms. Our laboratory coalition has developed highly sensitive and specific real-time PCR assays for detection of toxicity-associated dinoflagellates (*Pfiesteria piscicida*, *Pfiesteria shumwayae*, and *Gyrodinium galatheanum*) that can be used to explore the biology of these organisms and the epidemiology of associated human health impacts. Similar assays can be designed for detection of virtually any HAB or pathogenic microbial species in the estuarine environment. We present an overview of the development and deployment of molecular monitoring methods in the context of *Pfiesteria* in the Chesapeake Bay, a problem whose emergence was associated with an extraordinary media, policy, and public response. Use of these methods has enhanced ongoing cohort studies designed to determine the epidemiology of *Pfiesteria*-associated illness; basic laboratory research into the biology of *Pfiesteria* toxicity; and ongoing efforts to better understand the ecology of this fascinating microorganism.

Keywords: harmful algal blooms, HAB, dinoflagellates, *Pfiesteria*, *Gymnodinium*, monitoring, estuarine, real-time PCR

MICROBIAL COMMUNITY STRUCTURE/ FUNCTION RELATED TO WETLANDS AND BIOGEOCHEMICAL PROCESSES

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The compositions and activities of microbial communities in wetlands likely depend in part on their position along nutrient gradients formed from runoff from adjacent agricultural areas. An understanding of the relationships between community composition, nutrient status, and biogeochemical cycling may yield sensitive indicators of nutrient impacts. Bacteria are likely to respond to environmental change much more rapidly than do more complex organisms such as plants, and characterization of shifts n the composition of bacterial assemblages as a response to changes in nutrient concentrations may provide very sensitive early warning indicators of ecosystem change. These indicators could be useful in identifying ecologically sensitive concentrations of nutrients, and conversely, may be used to determine appropriate restoration endpoints.

We are currently investigating the relationship between the structure and function of bacterial assemblages involved in terminal carbon mineralization along nutrient gradients in freshwater marshes in Florida. This type of research will lead to a greater understanding of the response of these assemblages to nutrient impacts, and may lead to identification of sensitive indicators of the degree of impact along these gradients.

Keywords: Microbial indicators, biogeochemical cycling, microbial structure and function

CORRELATING CHANGES IN BACTERIOPLANKTON COMMUNITIES TO PRIMARY PRODUCTION AND EUTROPHICATION USING DGGE ANALYSIS OF 16S rDNA

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Microorganisms have long been recognized as vital components of estuarine ecosystems, yet the majority of these organisms remain uncultured and/or unidentified. Furthermore, in the environment microbes exist as complex communities often consisting of hundreds of taxa, many of which are unclassified. Fortunately, advances in molecular technologies have enabled the study of whole microbial communities through the use of 16S rRNA analysis without the culture and isolation of individual members. In particular, denaturing gradient gel electrophoresis (DGGE) analysis of 16S rDNA has proven to be an efficient method for the rapid comparison of bacterial communities. This technique separates gene fragments according to sequence, generating profiles of the communities which can then be used to compare community compositions. Fundamental changes in the composition of bacterial communities may be an important indicator of shifts in trophic dynamics, and subsequent changes in the overall fate of matter and energy in an estuary. We applied DGGE technology to landscape scale questions concerning interactions among phytoplankton populations and the associated bacterial communities in two estuaries with differing nutrient regimes. Water samples were collected from five sites in the mesotrophic ACE Basin estuary and five site in the oligotrophic North Inlet estuary and partitioned into a particle associated fraction and a free-living cell fraction, and the community DNA was extracted. A fragment of the 16S rRNA gene was amplified by polymerase chain reaction (PCR) and the resulting amplimers were separated by DGGE. The patterns generated are being used to determine changes in the composition of the bacterial community relative to changes in nutrient concentrations, chlorophyll concentrations (primary productivity), and phytoplankton community composition.

ULTRAVIOLET RADIATION EFFECTS ON MARINE BACTERIOPLANKTON: DNA DAMAGE AND CHANGES IN COMMUNITY STRUCTURE AND FUNCTION

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Bacteria play a vital role in mineralization of nutrients and provide a trophic link to higher organisms, yet the effects of ultraviolet radiation-B (UVB) upon bacterioplankton have been largely overlooked until recently. We have concentrated our efforts on measuring the primary effect of UVR on organisms, damage to DNA. Our studies have focused on the formation of DNA photoproducts (cyclobutane pyrimidine dimers and pyrimidine (6-4) pyrimidinone dimers) which are the unique photodamage products caused by UV-B radiation. Most recently we have been developing molecular assays which will provide an indication of oxidative damage to DNA Measures of DNA damage have been made in marine bacterioplankton as a function of diel solar cycles, depth in the water column, as well as the potential role of increased dissolved organic material in changing UVR effects.

The ability of solar radiation to change marine microbial community structure and function is now also under investigation. Solar radiation may result in a significant change in community structure and the change is wavelength dependent. While not universal, UVB was most often found to be associated with the greatest change in community structure. The results highlight the potential role solar radiation may play in determining microbial community structure and suggest that changes in radiation, such as increases in UVB caused by ozone depletion or decreases caused by water quality decline, may alter existing communities.

Managing Troubled Waters Revisited: Coastal Monitoring, 10 Years after the NRC Report

MANAGING TROUBLED WATERS—TEN YEARS AFTER

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In 1990 the National Research Council published a report entitled *Managing Troubled Waters: The Role of Marine Environmental Monitoring*, written by a committee I chaired. The report was undertaken because there was widespread discontent about the degree to which environmental monitoring results were, in fact, used in decision-making and because major federal monitoring initiatives were being started.

The report has been widely cited and has been used in the design and evaluation of monitoring programs around the United States and Canada, mainly because it articulated a not terribly sophisticated, common-sense approach to the design of monitoring programs consisting of seven steps, from defining expectations and goals to disseminating results. Although the framework seemed to help to improve the design of a number of regional monitoring programs, it is less clear that any of these has rigorously adhered to the design principles. The Chesapeake Bay Monitoring Program and the Regional Program for Trace Substances in San Francisco Bay are examined as examples. Although it has taken nearly a decade, the recommendation of the NRC report that disparate monitoring programs off Southern California be consolidated into a regional program is now being implemented. Recommendations regarding coordination of the NOAA Status and Trends Program and EPA's EMAP and their integration with regional monitoring programs were not implemented to a meaningful degree. Opportunities for these national programs to contribute to regional ecosystem management were lost as a result.

The emergence of multipurpose, automated observing systems was not anticipated in the 1990 NRC report; these offer new capabilities for monitoring important dynamic properties of ecosystems. Also, the current nationwide focus on determining and validating total maximum daily loads (TMDL) for impaired waters presents a new challenge for environmental monitoring in support of managing these troubled waters.

MANAGING TROUBLED WATERS: THE EVOLUTION OF THE EMAP-COASTAL MONITORING PROGRAM

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In 1990, Managing Troubled Waters concluded by stating three primary conclusions and then developing specific recommendations regarding their execution. Using the decade of the 90s, we examine the evolution of the U.S. EPA's Environmental Monitoring and Assessment Program's Coastal Monitoring component to assess adherence of that program to the Managing Troubled Waters guidance. These include: (1) the role of EMAP monitoring concepts in strengthening the role of marine environmental management at the national, regional, state and local scales, (2) the conduct of large scale regional and national monitoring efforts, and (3) the improvement of the designs of monitoring programs and the development of useful information products. We examine each of the Managing Troubled Waters recommendations and compare them to EMAP's conceptual promise, execution, mistakes, and adaptive development. The evolution of EMAP's coastal monitoring from largely regional monitoring in the early 1990s to a national program with state and local emphasis (Coastal 2000 Program) in 2000 has demonstrated a continuing desire to "push" that program toward a realization of Managing Troubled Waters lofty goals.

CHESAPEAKE BAY MONITORING PROGRAM ACCOMPLISHMENTS AND NEW DIRECTIONS

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In 1984 a comprehensive monitoring program was implemented for Chesapeake Bay in response to an extensive ecosystem study that found it was very difficult to quantify changes and problems in the Bay and its tributaries. This monitoring program was developed through a process of identifying key "management questions", translating these questions into monitoring objectives, and developing appropriate study designs to meet management information needs. The integrated monitoring elements include inputs of nutrients and sediments from major rivers, water quality, ecosystem processes, phytoplankton, zooplankton, benthos, submerged aquatic vegetation and contaminants. Information from the Chesapeake Bay Monitoring Program (CBMP) has been used extensively to meet its intended objectives -- trends in key water quality and biological indicators, identification of problems and development of mathematical models -- as well as many additional, and sometimes unanticipated needs -- supporting numerous research programs and understanding the impacts of unusual events (e.g. droughts and floods). The CBMP has been fine-tuned over the years to address emerging needs and new technologies while still maintaining the integrity of the long-term record. Continuing challenges and new directions include interpretation of complex biological community information, diagnosing specific causes of habitat and biological impairments, expanding the spatial and temporal coverage of the program to monitor shallow environments and short-term events, measuring attainment of water quality criteria/standards, supporting implementation of multispecies-based fisheries management, and broadening the dissemination of monitoring information to diverse audiences.

Keywords: Chesapeake Bay; monitoring; estuarine; water quality; management; indicators; biological monitoring

ENVIRONMENTAL INFORMATION AND THE TMDL PROGRAM: OPPORTUNITIES AND CHALLENGES

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The Federal Advisory Committee on TMDLs and the General Accounting Office both identified data deficiencies as an impediment to water quality management decisions. In response, EPA is working with its state partners to develop guidelines that strengthen water quality assessments, improve identification of impaired waters, and support management decisions including TMDL development. The major components of this Consolidated Assessment and Listing Methodology focus on monitoring design and data evaluation and interpretation to assess whether water quality standards are met. The monitoring design section presents different scenarios for designing water quality monitoring networks to meet the objectives of assessing the quality of all water resources throughout the state and characterizing impaired waters. The other section on making water quality standards attainment decisions focuses on data quality and quantity issues and data analysis techniques for each of the primary types of data used to interpret water quality standards–physical, chemical, biological, habitat, pathogens, toxicity. This presentation will present the recommendations of this guidance and invite feedback on the draft document.

THE COASTAL COMPONENT OF THE U.S. INTEGRATED OCEAN OBSERVING SYSTEM

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The combined effects of human activities and natural variability present significant challenges to the goals of protecting, restoring, and sustaining ecosystem goods and services in coastal environments. Meeting these challenges and resolving conflicts in an informed fashion will require more timely detection and prediction of environmental changes and their consequences and more timely access to relevant environmental information by policy and decision makers. There is an immediate need to make more effective use of existing resources and new technologies to provide more timely detection and prediction of changes in coastal systems and the effects of these changes in people. A sustained and integrated ocean observing system (IOOS) is needed to improve (1) climate predictions and the effects of changes in the weather on coastal populations; (2) the safety and efficiency of marine operations; (3) efforts to sustain and restore healthy coastal marine ecosystems and living marine resources; and (4) compliance monitoring and evaluations of the efficacy of environmental policies for coastal ecosystems. Although the agencies and departments responsible for these services all require environmental observations, separate programs have evolved for collecting, managing, analyzing, and applying environmental data. Consequently, there is too much redundancy, programs are often not compatible with each other, and individual programs are inevitably underfunded, limited in scope, and target a limited number of user groups. A more cost-effective approach is needed that coordinates and integrates many of the elements of these programs to minimize redundancy, be more comprehensive, provide more timely access to data and information, and satisfy the information needs of a greater number of user groups. By formulating and implementing a plan for regional observing systems that are nationally coordinated and locally relevant, a wider array of users will be more effectively served with relatively modest increases in costs relative to the additional benefits. This is the purpose of the IOOS.

Integrated Assessments of Coastal Watersheds

INTEGRATED ASSESSMENT: REFLECTIONS OVER THREE DECADES

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Over the past 30 years, a number of programs have added value to the synthesis of information for use in decision making; that is, lessons for conducting integrated assessments. The IBP, NEPA, NAPAPA, EMAP, REMAP, MARA, MAIA, STAR, Eagle Mortality Task Force, and similar programs have all provided insight into important factors needed effective assessments. Assessment is a process, not a product. The effective assessments embody this principle. In addition, however, there are a number of factors that are common among effective assessments. These common factors will be discussed during this presentation. Some of the factors that emerged from effective assessments include: 1) Management-relevant questions guide the program; 2) Teams are interdisciplinary, not multidisciplinary; 3) Multiple models and multiple approaches are used; 4) Interim products are provided; 5) Pluralistic assessments are produced for multiple audiences; 6) Comparative, relative risk perspectives prevail; 7) A science-policy liaison team is formed; 8) Critics are part of the Team; 9) They begin with the end in mind; and 10) Assessment is the 1st step, not the last.. These and similar lessons will be discussed during the presentation.

Keywords: Integrated assessment, aquatic ecosystems, policy, management

USE OF HYDROLOGIC, GEOLOGIC, AND CHEMICAL DATA TO STUDY NUTRIENT AND PESTICIDE TRANSPORT AND TRANSFORMATION IN TWO SMALL AGRICULTURAL WATERSHEDS IN THE MID-ATLANTIC COASTAL PLAIN

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The Mid-Atlantic Coastal Plain includes thousands of small watersheds that drain directly into tidal streams, estuaries, and the Atlantic Ocean. Results from an integrated study of select non-tidal watersheds, representing a particular set of physical features common to other non-tidal watersheds, can be applied to understanding chemical transport to tidal tributaries and to developing effective land-management practices for areas where intensive study is not possible. Two small agricultural watersheds, in different physical settings of the Coastal Plain, have been studied intensively to determine the factors controlling the movement of nutrients and pesticides through ground water and surface water. These watersheds are located on the western side of the Delmarva Peninsula and drain into the Chesapeake Bay. The Chesterville Branch watershed includes more than 90 percent agricultural land on the uplands with forested riparian zones along the stream. Nitrate concentrations are commonly greater than 10 mg/L as nitrogen in both ground water and surface water. Ground water containing nitrate flows beneath and bypasses the riparian zone and discharges relatively unaltered to surface water at this site. The upper Pocomoke River watershed is extremely flat and naturally poorly drained. Extensive ditches drain the agricultural fields and form the headwaters of streams. High concentrations of nitrogen and phosphorus enter the unbuffered ditches from direct runoff and along short ground-water flow paths. Nutrient concentrations decrease downstream as discharge of deeper ground water increases. Pesticides and their metabolites are detectible year-round in surface water at both sites, indicating a ground-water source for pesticides.

Keywords: Coastal Plain, non-tidal watersheds, nutrients, pesticides, agricultural effects, water quality

CHARACTERIZING AND STATISTICAL MODELING OF BACTERIAL (*E.COLI*) OUTFALLS FROM WATERSHEDS THAT CONTRIBUTE CONTAMINATED STREAMFLOW TO THE SHORE ZONE OF SOUTHERN LAKE MICHIGAN

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Two watersheds in northwestern Indiana were selected for detailed monitoring of bacterial outfalls (*Escherichia coli*) into Lake Michigan. The Little Calumet watershed drains an urbanized area with treatment plants that release raw sewage during storms, while the Derby Ditch watershed drains the Great Marsh, a wetland complex that has been disrupted by ditching and limited residential development. Monitoring at Derby Ditch from 1997 to 2000 indicated that *E.coli* concentrations increase during storms with the highest concentrations generally occurring during rising streamflow. Monitoring at the outlet of the Little Calumet River in 1999 and 2000 indicated that *E.coli* concentrations remain steady (*ca*. 100 cfu/100 ml) during dry periods but vary over two orders of magnitude during storms. Sewage overflows caused concentrations to increase to over 10,000 cfu/100 ml for several hours. Multiple regression analysis indicated that 60% of the variability in measured outfalls of *E.coli* from Derby Ditch (N=88) could be accounted for by a model that utilizes continuously measured rainfall, stream discharge, soil temperature and depth to water table in the Great Marsh. A similar analysis indicated that 80% of the variability in measured *E.coli* concentrations at the outlet of the Little Calumet River (N=51) could be accounted for by a combination of continuously measured water-quality parameters including nitrate and ammonium. These models, which can be applied on a real-time basis, constitute part of an *Early Warning System* for predicting beach closures that is a goal of Indiana's Interagency Task Force on *E.coli*.

Keywords: *E.coli* bacteria, storm-period monitoring, statistical forecasting equations

USGS/BEST STUDIES IN SUPPORT OF THE EMAP WESTERN PILOT STUDY

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Some of the core screening methods from the USGS Biomonitoring of Environmental Status and Trends (BEST) program were included in the EMAP Western Pilot Study to help characterize chemical stressors in estuarine and coastal habitats along the Pacific coast of the US. One of these core screening methods, the H4IIE bioassay, measured the concentration of tetrachlorodibenzodioxin equivalents (TCDD-EQs) in fish from small estuaries in each of three states, Washington, Oregon and California. The amount of dioxin-like potency in the fish was low in most cases. The fish with the greatest TCDD-EQs were collected in the Columbia River estuary, Tillamook Bay, and the Yaquina River. Fish from Los Angles Harbor and Long Beach Harbor also had significant amounts of dioxin-like potency as measured by the H4IIE test. In addition to the standard solid-phase toxicity tests with amphipods used in the EMAP program, additional BEST methods, which measured toxicity using porewater tests with early life stages of the sea urchin, *Arbacia punctulata,* were conducted at 50 stations on the coast of each of three states. Sea urchin embryological development tests were the most sensitive overall, with 39% toxic stations on the Washington coast, 44% on the Oregon coast, and 89% on the more anthropogenically-compromised coast of California. Several of the samples that were toxic to urchin embryos, particularly in the heavily populated areas of Southern California, also exhibited toxicity in the fertilization test. Highly significant associations between sediment toxicity and the degree of contamination were observed.

Keywords: Sediment Quality Triad, porewater toxicity, H4IIE, BEST, sea urchin, amphipod

INTEGRATED ASSESSMENTS OF THE ENVIRONMENTAL CONDITION OF CHESAPEAKE BAY

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The Chesapeake Bay, the Nation's largest estuary, has experienced environmental degradation due to nutrient enrichment, contamination, loss of habitat, and over-harvesting of living resources. Resource managers need information on the extent of degradation to formulate restoration strategies. The presentation illustrates approaches our organizations are taking in conducting integrated resource assessments by reviewing examples for two problems in Chesapeake Bay (sediment contamination and nutrient loading). Sediment contamination is primarily found in small systems around the bay (i.e., harbors, embayments, and tidal rivers). The EPA EMAP approach to monitoring and assessment is to collect a suite of indicators at sites selected using a probability design. The design allows one to estimate areal extent of estuarine conditions, and the suite of indicators sampled permits associations to be made between stressors and effects. Approximately 5% of the Bay has sediment with contaminants above the Long and Morgan ER-M levels, while 9% of the small systems exceed these levels. Research is currently underway to conduct integrated assessments relating landscape metrics to estuarine condition. Quantitative relationships have been developed which indicate that sediment contamination levels increase with urban land and point source loading in the local watershed, while they decrease with increasing nonforested wetlands acreage. Further work is being conducted to refine these relationships. Nutrient loading is a system-wide issue, contributing to hypoxia in the mainstem portion of the bay and the larger tributaries, as shown by data collected for the Chesapeake Bay Program. The USGS has conducted an integrated study of the nutrient sources and loadings in surrounding watersheds that are contributing to hypoxia in the Bay. The integrated approach includes relating nutrient sources to loadings delivered to the Bay, understanding the influence of ground water on the delivery, and examining how the nutrient loadings have changed over time. About 20 percent of the nutrients from sources in the watershed ultimately reach the Bay, based on results of a statistical model that links nutrient sources to loadings (SPARROW model). On average, about half of the nitrate from the non-point sources travels through the shallow ground-water system, but varies depending on the geology and source. Finally, nutrient loads to the Bay are not showing a large decrease over time in spite of nutrient reduction efforts. The lack of a trend is related to a lack of trend in stream flow and the buffering by ground water, both of which influence the delivery of nutrients to the Bay.

AN INTEGRATED ASSESSMENT OF THE CAUSES, CONSEQUENCES, AND SOLUTIONS TO GULF OF MEXICO HYPOXIA

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The recently completed integrated assessment of hypoxia in the northern Gulf of Mexico illustrates five essential characteristics of the type of assessment increasingly demanded from the scientific community on environmental issues. Today's assessments are asked to be broadly integrative and synthetic, answer policy-relevant questions, involve solid peer review and full public participation, be based on high quality monitoring data, and be predictive.

The hypoxia assessment, under the auspices of the National Science and Technology Council's Committee on Environment and Natural Resources, pulled together the results of more than a decade of research in many disciplines to construct a century-long profile of change in the Gulf and the Mississippi River basin. This evidence indicates that excess nitrogen from the drainage basin, coupled with hydrologic and climatic factors, drives the onset and duration of hypoxia in the northern Gulf of Mexico. Measures to reduce nitrogen flux, including improving the efficiency of agricultural use, reducing point sources, and restoring natural denitrification in wetlands and riparian areas, were identified and their costs and benefits estimated.

Based on the assessment, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, consisting of federal, state and tribal policy-level officials, developed an action plan which has been submitted to Congress. The Task Force was an interested, critical, and constructive "customer" for the integrated assessment, serving to keep it focused on policy-relevant issues. Time will tell whether these mechanisms are successful in securing the resolve and resources needed for an effective solution to the hypoxia issue.

Nearly 50 scientists in six topic teams wrote the reports that are the foundation of the assessment. Extensive peer review was used to ensure the quality and credibility of these reports. Public comment was invited on the six reports and the assessment in draft form. Central issues from all perspectives were discussed at a science meeting which produced a remarkable degree of consensus as the assessment was completed. Nevertheless, a certain amount of controversy remains, perhaps not unexpected given the context of forging a political consensus on action.

Monitoring data from NOAA-supported studies in the hypoxic zone, from USGS water programs in the basin, and from USDA's agricultural economic and environmental programs supported compelling analyses that enabled a scientific consensus about causes, consequences and solutions. Guiding progress from this point will require continuing these monitoring efforts and augmenting them with higher resolution analyses needed for local decision-making. Today's predictive models indicate that reducing nutrient flux to the Gulf by 20-30% will increase bottom-water dissolved oxygen by 15-50%. That forecast provides confidence to begin action but more comprehensive and accurate models will be needed to interpret progress and sustain the actions needed to solve the hypoxia problem in the Gulf of Mexico.

Coastal Water Criteria and Sediment Quality Guidelines

DEVELOPMENT, FIELD VALIDATION, AND IMPLEMENTATION OF SEDIMENT QUALITY TARGETS IN MINNESOTA: COMPARISONS WITH THE USES OF SEDIMENT QUALITY GUIDELINES ELSEWHERE IN THE GREAT LAKES REGION

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Under the Great Lakes Water Quality Agreement, remedial action plans (RAPs) must be developed to support the restoration of impaired uses at Areas of Concern (AOCs) in the Great Lakes basin. In the St. Louis River AOC, a number of designated uses have been impaired due to the presence of contaminated sediments. To support the RAP process, the Minnesota Pollution Control Agency (MPCA) has worked with several collaborators (including consultants and federal agencies) to develop biologically-based sediment quality targets (SQTs) to support the assessment and management of contaminated sediments in this transboundary waterway between Minnesota and Wisconsin. In addition, feedback on this project was obtained from the local RAP group, the Wisconsin Department of Natural Resources, and the Science Advisory Group on Sediment Quality Assessment. The U.S. EPA's Great Lakes National Program Office (GLNPO) funded this project and has been an important partner to the MPCA. A number of empirical and theoretical approaches to the derivation of sediment quality guidelines were reviewed and evaluated. The consensus-based threshold effect concentrations (TECs) and probable effect concentrations (PECs) were adopted as Level I and Level II SQTs, respectively, for the protection of sediment-dwelling organisms. An evaluation of predictive ability confirmed that these SQTs provide a reliable basis for predicting the presence and absence of sediment toxicity in the St. Louis River AOC. Frameworks were developed within which to use the SQTs, and a variety of uses of the SQTs were proposed.

Keywords: sediment quality targets, sediment quality guidelines, sediment assessment, Great Lakes, Area of Concern

DEVELOPMENT, FIELD VALIDATION AND IMPLEMENTATION OF SEDIMENT QUALITY GUIDELINES FOR SALTWATER AND FRESHWATER SEDIMENTS OF FLORIDA

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The State of Florida has been involved with interpretation of sediment chemistry data for nearly two decades. Contaminated sediments first became an issue in the coastal areas with regulatory issues associated with deep-water ports. For that reason, the state first developed a reference “tool” to better understand trace metals contamination in differing geophysical regions in the state. However, managers needed more information on whether contaminants found in sediments were of biological concern.

Following a review and evaluation of several alternative approaches, the state of Florida adopted NOAA’s approach to the development of saltwater guidelines. In 1994 the Department of Environmental Protection published informal (i.e., non-regulatory) guidelines for marine sediments to provide information about concentrations that are associated with adverse biological effects in Florida coastal waters. The partnership continued as NOAA conducted investigations of six major estuaries in Florida, allowing further ability to calculate predictability of the guidelines. These and additional data from NOAA and EMAP surveys subsequently were used in field validations of the predictive abilities of the guidelines.

The resulting data and technical publications currently are utilized by coastal management programs to assist in management of contaminated sediments, such as in the Tampa Bay Estuary Program. In 2000, the state of Florida began to develop guidelines for freshwater sediments, using an approach similar to that applied to saltwater sediments. Thus far, a freshwater database has been compiled and preliminary analyses are underway.

CHARACTERIZATION AND SPATIAL DISTRIBUTION OF HEAVY METALS IN SEDIMENT FROM CEDAR AND ORTEGA RIVERS SUBBASIN, FLORIDA

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The Cedar and Ortega rivers subbasin, a tributary of the lower St. Johns River in Florida, is a complex environment where both natural and anthropogenic processes influence the characteristics and distributions of sediments and contaminants, which in turn is of importance for maintenance dredging and pollution control. This study was conducted to ascertain the characteristics and spatial distributions of lead (Pb), copper (Cu), zinc (Zn), cadmium (Cd), and mercury (Hg) from sediments in the subbasin using field measurements and 3-D kriging estimates. Sediments were collected from three sampling depth intervals (i.e., 0-0.10, 0.11-0.56, and 0.57-1.88 m) in 58 locations using EPA EMAP site selection protocol. Concentrations of Pb ranged from 4.47 to 420.00, Cu from 2.30 to 107.00, Zn from 9.75 to 2,050.00, Cd from 0.07 to 3.83, and Hg from 0.03 to 4.29 mg/kg dry wt. Overall, most of the metals accumulated within the top 0.56 m of sediment and all of the mean metal concentrations within this range exceeded the threshold effect levels (TEL). Our kriging estimates revealed that Pb concentrations decreased significantly in the first sampling interval (0-0.10) as compared to the second sampling interval (0.11-0.56), whereas Zn and Cu concentrations were still enriched in the first sampling interval. It appeared from the kriging estimates that the Hg loading was not only from the Cedar River, but also from the Ortega River and other sources since Hg was distributed more evenly across the Cedar and Ortega rivers subbasin. Comparison of the aluminum (Al) normalized metal concentrations indicated that most of the metal contamination had accumulated within the top 0.56 m of sediment. These normalized metal concentrations exceeded background levels by factors of 2 to 10, and therefore could pose a threat to the health of aquatic organisms.

Keywords: Heavy metals; Kriging, River basin; Sediment; Spatial distribution

EPA's WATERBORNE MICROBIAL DISEASE CONTROL STRATEGY

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In 1998, pathogens were the second most frequent cause of impairments to waters under the Clean Water Act. Impairment was primarily due to the increasing populations of humans and livestock, and their wastes within watershed areas. EPA has a number of existing mandates, regulations and initiatives such as the Interim Enhanced Surface Water Treatment Rule and EPA's Beach Action Plan which are important in reducing health risks from pathogens. These important efforts need to continue. EPA is adopting a strategy for future actions to integrate and extend its current programs to reduce adverse impacts of microbiological contamination in water. The strategy will guide decisions on the most effective use of available resources, support communication and partnerships with stakeholders, and enhance public communication. The specific goals of the strategy include identification of priority activities for 1) the ability to monitor for significant known pathogens and emerging pathogens, 2) identification and control of pollutant sources so that waters will meet protective use criteria, 3) coordination of regulatory and research activities, 4) development of regulatory approaches, 5) providing for research and development, and 6) participation of public agencies and stakeholders.

THE U.S. EPA PROGRAM FOR DEVELOPMENT OF ECOREGIONAL-BASED NUMERIC NUTRIENT CRITERIA: ESTUARIES AND COASTAL WATERS

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The "greening" of the Nation's waters from nutrient over-enrichment led to the development in the EPA Office of Water of the National Nutrient Criteria Program whose responsibility is to implement a program that assists States and Tribes in improving and maintaining nutrient levels that ensure the meeting of designated uses including "fishable and swimmable" conditions. To date, Nutrient Criteria Technical Guidance Manuals have been developed for Lakes and Reservoirs and Rivers and Streams with Estuaries and Coastal Waters and Wetlands Manuals planned for publication in early 2001 (www.epa.gov/ost/standards/nutrient.html). The manuals describe how to assess a waterbody's nutrient status, develop nutrient criteria and databases and monitor for nutrient program implementation effectiveness. Additionally, EPA plans to soon publish 17 (8 lakes and reservoirs, 8 rivers and streams, and 1 wetland) ecoregion-based documents entitled, "Ambient Water Quality Criteria Recommendations" (currently focused on nutrient reference conditions) as a starting point for full development of ecoregional-based nutrient criteria by the States and authorized Tribes. Other such documents will be published in the future or as data become available. For the Symposium, discussion focuses on the role of monitoring in estuaries and coastal waters. The "reference condition/site" approach, as one of the elements of criteria development, serves as as a benchmark of minimally impaired aquatic ecosystems. At the implementation phase of the nutrient criteria program, assessment of program performance also requires appropriate monitoring data with multiple objectives. Complication in cause and effect assessments can arise because variability in estuarine physical (vertical density stratification and flushing) and biological processes (grazing) can modulate the anthropogenic (cultural) component of the nutrient supply problem. In coastal waters, the water mass identity and tracking problems make cause and effect relationships difficult to assess. These problems are inherent in criteria development. Examples of ecosystem processes that can confound the anthropogenic nutrient enrichment signal will be discussed.

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SHALLOW WATER REMOTE SENSING TECHNIQUES FOR ESSENTIAL FISH HABITAT CHARACTERIZATION

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Mapping shallow water habitats can be achieved employing various survey and analysis techniques. The intent is to maximize spatial coverage and data utility. This paper presents an overview of the techniques used to map shallow water benthic habitats in a shallow water area of Narragansett Bay, Rhode Island. The survey area encompasses approximately 500,000m^2 with depths ranging from 0-6.5 m. The purpose of this investigation is to document baseline ecological conditions, including quality and extent of eelgrass beds and substrate type, and respective community structure in a manner that permits gross changes in habitat characteristics and population to be discerned in the event of potential dredging-related impacts. Data acquisition platforms include side scan sonar, singe beam bathymetry, video transects, "planview" bottom photography, and sediment profile photography. The integration of these data types in a GIS is key to delineating Essential Fish Habitats (EFH) and other bottom types. An overview of the investigation is presented from planning to surveying and analysis. Initial results are also presented.

Key words: Habitat, GIS, EFH, dredging, community structure

Linking Coastal Monitoring with Research & Management

EFFECTS OF SALINITY ON AGRICHEMICAL TOXICITY IN EURYHALINE FISH: MECHANISM AND POTENTIAL STRUCTURE-BASED HAZARD ASSESSMENTS

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Hazard assessments of environmental chemicals in aquatic systems are routinely based upon acute and chronic toxicity values at which no adverse effect or a specific percentage of the population (i.e. 50%) is adversely affected. Typically these values are determined in sentinel species of a single phylum and represent that phyla and the type of aquatic system in which that phyla normally resides (i.e. freshwater, marine, estuarine). Toxicity tests are generally performed using specific “approved” water quality parameters, which are unchanged throughout the exposure period. Although these protocols are warranted in freshwater and marine species, estuarine organisms are usually exposed to a range of water chemistries resulting from altered environmental factors. In a typical estuary, salinity regimes can range from 2 to 30 ppth within a 24 hr period. However, the impact of salinity upon toxicity of environmental chemicals is rarely considered in hazard assessments. An example of an environmental chemical that is significantly more toxic at higher salinity to certain species of euryhaline fish is the carbamate insecticide aldicarb. Based upon mechanistic studies examining this interaction, it is possible that structure activity relationships may be used to direct regulators in the choice of sentinel species and exposure conditions, which will provide a more accurate hazard assessment.

Keywords: Hazard Assessment, Salinity, Estuary, Aldicarb, Bioactivation, cholinesterase

THE ROLE OF SEA GRANT COASTAL RESEARCH IN THE DEVELOPMENT OF REGIONAL MONITORING EFFORTS

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The 30 Sea Grant Programs around the country conduct a large and vigorous research program in marine and freshwater coastal regions of the U.S. Sea Grant utilizes the skills and resources of several hundred U.S. universities and research institutions through federal/state partnerships. The strong connections between Sea Grant and university scientists ensures access to some of the top researchers in the country and sensitivity to regional environmental issues. Although Sea Grant programs individually tailor research programs to best fit the needs of their state, the research must address general national program goals. In addition, special national strategic initiatives ensure that broad national research priorities are addressed in a multi-institutional and interdisciplinary fashion. Examples of Sea Grant funded research relevant to the development of larger monitoring programs are numerous and include detailed input-output models of toxic chemicals in the Great Lakes; national programs examining invasive species such as zebra mussels, Phragmites, green crabs and several other species; a national program funding fisheries habitat investigations in coastal marine and fresh waters; and numerous state programs designed to delineate and solve environmental problems affecting marine resources. Ongoing and past Sea Grant research can often be the crucial for delineating important biotic, chemical, and physical factors that should be included in larger-scale monitoring and assessment efforts such as EMAP. This research may also be particularly useful in identifying the range of variation and environmental influences on specific parameters. Sea Grant research programs can be a strong partner in large-scale monitoring programs.

Keywords: research, marine, freshwater, monitoring programs

CITIZEN VOLUNTEER, WATER QUALITY MONITORING ON ALABAMA'S COAST: CASE STUDIES FROM TWO EMBAYMENTS

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Alabama Water Watch (AWW) is a citizen volunteer, water quality monitoring program that began in 1992 with funding from the Alabama Department of Environmental Management and the U.S. Environmental Protection Agency, Region 4. The program is coordinated from the Auburn University Fisheries Department and provides training workshops (nine levels), database management and data summary/dissemination for the groups. AWW currently has 70 active groups and, since program inception, monitors have assessed about 20,000 samples from 1,140 sites on 500 water bodies statewide. Two groups affiliated with AWW on the Alabama coast are Weeks Bay Water Watch and Wolf Bay Watershed Watch. For the past 4-7 years, they have regularly sampled scores of sites and have identified water quality trends, areas of pollution and strategies for bay restoration and protection. One strategy for increasing public and policy maker awareness and action is to feature the work of the bay groups in a new, AWW Coastal Report Series. The reports are designed to make water data of citizen volunteers and researchers more accessible and understandable to the layperson. This presentation will offer highlights of these reports, addressing questions such as "What do Volunteers Do?" "What Have Volunteers Found?" "Is Volunteer Information Reliable?" and "Why is Volunteer Monitoring Important?" A case is made for the full participation of citizen groups in coastal management, including more substantial and extensive use of their quality assured data and inputs in all aspects of planning, assessment, analysis and action.

Keywords: Citizen Volunteers, Water Quality, Coastal Monitoring

MID-ATLANTIC INTEGRATED ASSESSMENT – LESSONS LEARNED

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The U.S. EPA Office of Research and Development has partnered with EPA's Region 3 since the early 1990's to test, evaluate and demonstrate the applicability of sound science to Agency programs and policies. This partnership is designated as the Mid-Atlantic Integrated Assessment (MAIA) and covers all Region 3 states: Pennsylvania, Virginia, West Virginia, Maryland, Delaware and the District of Columbia, plus the parts of New York, New Jersey, and North Carolina in the respective Chesapeake Bay, Delaware Estuary, and Albermarle-Pamlico Sound watersheds.

The MAIA mission is to provide integrated scientific knowledge to support environmental decision-making in the Mid-Atlantic region to EPA's Region 3, and the states, counties, local municipalities, and the non-governmental organizations (NGO's) in the Region as well.

The goals to reach the mission were:
- Develop acceptable and valid environmental indicators for natural resource and human protection
- Merge biological data with physical and chemical data into dynamic and useful assessments;
- Integrate socio-economic data into the environmental assessments;
- Make Region 3 the "best characterized" area for environmental conditions to date.
- Use assessments to make management decisions and influence public perception and opinion;
- Foster integrated environmental management based upon relative risks.

The overall assessment questions to be addressed were:
- What is current condition?
- Is it changing? What are trends?
- What is causing problems, if there are any?
- What can we do about it?
- Are we making a difference?

Some of the major reports either completed (*), or soon to be completed, are:

- Regional Land Use/Land Cover *
- An Ecological Assessment of the United States Mid-Atlantic Region, A Landscape Atlas*
- Condition of Mid-Atlantic Estuaries *
- Pesticides in Ground Water of the Mid-Atlantic Region *
- From the Mountains to the Sea, The State of Maryland's Freshwater Streams *
- State of the Highlands' (Pennsylvania/ West Virginia/Virginia) Streams
- State of the Forests

Based upon this work to date, the Region 3/ORD partnership has found seven (7) key lessons and several strategic policy implications. The overall good news is that the environment is showing progress in physical and chemical parameters, but as EPA's goal is a safe and sustainable environment for humans and other living organism, we are not reaching it yet.

In specific, MAIA found:

- Living organisms (Benthic, Fish, Trees, and Birds) are stressed and impaired, throughout the Region;
- Biological condition, ecological condition and land use/land cover are all linked;
- Biological indicators do integrate effects of chemistry, habitat, pathogens and other stressors;
- Chemistry alone does not provide a complete picture of environmental condition;
- Habitat loss and degradation is a major environmental stressor in the Region;
- Forest fragmentation is wide-spread throughout the Region;
- Non-indigenous invasive species are a major problem in the Mid-Atlantic.

The MAIA program also felt that three (3) management insights flowed out of the work. The use of biological indicators as endpoints of interest highlighted that a media (air, water, pesticides, etc.) by media approach alone is not sufficient to protect and sustain living organisms, humans and other animals, and their habitats. A more integrated environmental management approach is needed to assess all stressors to the living organisms and develop a relative ranking of their importance. Second, a more coherent and efficient ecological engineering approach should be applied to a watershed to protect living organisms. Lastly, a better biological monitoring scheme needs to be used to report the progress of the ecological engineering efforts.

REAL-TIME MONITORING AND REPORTING OF WATER QUALITY FOR THE CHARLES RIVER AND BOSTON HARBOR – THE "FLAGGING PROJECT"

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The Lower Charles River and Boston Harbor are an improving urban recreational watershed, affected by sewage-derived pathogens from illegal sewer connections, stormwater, and CSOs.

As part of the BEACH/EMPACT program, EPA is working with local organizations to enhance existing monitoring and public notification efforts at nine river boathouses and 20 harbor area beaches. From 1998 to 2000, the river and beaches were monitored on a daily or weekly basis for two bacterial indicators (fecal coliform and *Enterococci)*. Using on-site flagging, the internet and other media, boaters and swimmers were notified daily whether bacterial indicator levels exceeded established standards of risk.

To improve real-time public notification, we field-tested at MDC beaches EPA's new 24-hour *Enterococci* method and showed that the new method provided results similar to the existing 48-hour method.

Because wet weather carries pathogens and indicator bacteria, a predictive rainfall-based advisory protocol has been established for the Charles River. Based on monitoring and river time-of-travel, the CRWA is continually validating a protocol to flag at boathouses when rainfall exceeds certain thresholds. In 1999, the CRWA flagged boathouses correctly 87% of the time.

The MWRA, with MDC, is also developing a rainfall-based posting protocol for four harbor beaches. Acounting for tidal effects, a logistic-regression model has been developed to set site-specific posting thresholds.

The partnerships developed before and during this EMPACT project appear to be sustainable, promote improvements in water quality and protect public health. Importantly, the project has developed public support for costly improvements in sewer infrastructure at Wollaston Beach, one of the most "flagged" area beaches.

Keywords: "EMPACT", "*Enterococci*", "indicator bacteria", "rainfall-based advisory", "real-time monitoring", "water quality"

SOUTH FLORIDA ECOSYSTEM ASSESSMENT (REMAP)–TREND MONITORING FOR RESTORATION?

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The U.S. Environmental Protection Agency (EPA) Region 4 initiated a project in 1992 to assess the effects of mercury contamination on the South Florida Everglades Ecosystem. This project was designed around the EPA Ecological Risk Assessment Framework and implemented using a statistical survey design to conduct synoptic surveys during the wet and dry seasons from 1994-1996. During this first phase of the project soil, water and biota were sampled at about 500 sites throughout the 9,600 km^2 marsh to assess the effects of hydropattern, phosphorus loading, habitat alteration and mercury contamination on the marsh ecosystem. The Phase I report (EPA 1998) found there were significant interactions among water depth, TOC, TP, and SO_4 concentrations, food web dynamics and fish mercury concentrations. These interactions exhibited different spatial patterns in the area north of Alligator Alley, between Alligator Alley and Tamiami Trial and south of Tamiami Trail in Everglades National Park. Three conceptual models were developed, one for each of these three areas, as part of the Phase I report to describe the pathways and interactions among factors affecting fish mercury concentration.

In 1999, EPA initiated Phase II of the Everglades Ecosystem Assessment Project which added parameters in pore water, floc, macrophyte tissue, and plant community sampling in addition to the constituents and media sampled in Phase I. Wet and dry season samples were collected at about 240 marsh sites in 1999. Six system wide synoptic surveys provide a spatial data base from which a full range of water depths can be compared with other key interacting variables. Selected variables (e.g., TOC, TP, SO^4, S^{2-}, HgT, MeHg, tissue Hg and BAF) will be presented to illustrate changes among wet and dry cycles, seven geographic subareas and system wide gradients which support the interactive conceptual models being developed to address the spatial changes in the system. Important changes in TP and mercury contamination were observed in 1999.

Monitoring and Assessment of Public Health Threats in Coastal Waters

HARMFUL ALGAL BLOOMS

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Harmful algal blooms (HABs) cause public health and living natural resource risks worldwide. HABs are caused by microalgae that produce neurotoxins, cytotoxins, or other bioactive compounds that can disable or kill animals, including humans. When causative organisms are known and recognized, monitoring programs can be established based on seasonality and distribution of historical blooms or routine monitoring at sentinel sites. For potential HABs, a monthly microalgal monitoring program may or may not suffice, depending on habitat and species. For known HABs, the monitoring program depends on microscopic identification of toxic species in live (or preserved) water samples. Severity is often interpreted based on cell abundance, actual toxins measured in the water, or effects (e.g., animal mortalities). Recent advances in protocol involve new technologies where partnerships are a requisite in developing and conducting coastal monitoring programs. Three examples of such advances include: 1) Satellite color sensors: Sensors can detect chlorophyll levels of an existing bloom, and images can be used to track the movement of blooms. If forcing factors are known, bloom movement can be predicted. 2) In situ sensors: Buoys, mooring arrays, or other platforms can be equipped with in-water sensors that can detect species (whole cells, fragments, genetic material) or toxins. Data can be telemetered to a base station by satellite. 3) Volunteer coastal/offshore sampling program: Volunteer fishermen, boaters, and other users can be enlisted to collect samples for analyses at a central receiving laboratory. All samples require partnerships that may involve federal, state, academic, and private contributors/collaborators. Partnerships can and do work for HAB monitoring and assessment.

EVOLVING METHODOLOGY FOR STUDYING MARINE VIBRIOS

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Marine vibrio bacteria are a major cause of illnesses and the leading cause of deaths related to seafood consumption in the U.S. Further, vibrio infections can be acquired during recreational use of coastal waters. Recent advances in DNA gene probe and PCR methodologies to detect and enumerate vibrios in seafood and environmental samples are integral to assessing the human health risk associated with exposure to these organisms. Non-isotopic gene probes are suitable for use with direct plating of samples and provide a powerful molecular epidemiology tool for tracing seafood products to food-borne human illness. The ability to enumerate pathogenic and nonpathogenic vibrios greatly enhances the utility of these probes. Using appropriate DNA extraction methods for removal of inhibiting compounds, followed by PCR analysis, oyster samples can be rapidly screened for target DNA. This methodology will detect an initial contamination level of 10^0 to 10^1 CFU of *Vibrio parahaemolyticus*/g of oyster homogenate after overnight incubation (final counts of 10^4 to 10^8 CFU/g).

Keywords: vibrio, methods

MEASURING WATER QUALITY: MEMBRANE FILTRATION ON MULTIPLE TUBE FERMENTATION?

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The quality of recreational waters and shellfish growing waters is maintained by limiting the density of microorganisms associated with excreta from humans and other warm-blooded animals. The fecal indicator bacteria are commonly enumerated using membrane filter (MF) procedures for recreational water samples and by the multiple tube fermentation (MTF) procedure for shellfish growing waters. The use of the MTF procedure has been criticized because of the great imprecision of the microorganism density estimate that results from the test, since the upper 95% confidence interval can be many times the value of the mean, depending on the number of tubes used. The MF technique likewise has been criticized because it is believed that water samples with high particulate density might block membrane pores or interfere with bacterial growth on the membrane. Comparison of results from multiple assays performed by the MF and MTF procedures on the same water samples empirically show the wide discrepancies from the mean indicator densities that occur with the MTF technique. Variations in the multiple tube procedure to improve method precision, such as the use of 50-well trays, will be discussed. The advantage of on-site filtering and application of the membrane to a transport medium, which allows shipment to a central laboratory, will also be addressed.

THE UTILITY OF ANTIBIOTIC RESISTANCE AND DNA FINGERPRINT PROFILING FOR DISCRIMINATING SOURCES OF FECAL POLLUTION IN SURFACE WATERS

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Knowing the source of fecal pollution in water is paramount to estimating human health risk, as well as designing remedial actions. Historically, members of the coliform group of bacteria have been commonly used to measure fecal pollution, however their ubiquitous nature in warm-blooded animals has precluded their use as discriminatory tools. To address this need, genotypic and phenotypic methods have been developed with the intended purpose of identifying subtypes of bacteria associated with specific animal species. Of these techniques, ribotype (RT), pulsed field gel electrophoresis (PFGE) and multiple antibiotic resistance (MAR) have received considerable attention and have been shown to display beneficial discriminating properties when coupled with statistical analyses. However, it is necessary to realize the specific limitations of each technique so that they are properly applied and interpreted for individual situations. For example, a genotypic method such as PFGE is extremely useful for pinpointing specific clones of bacteria, whereas RT serves to identify certain clusters of bacteria within a species. The latter method has been successfully used to identify human and non-human sources of *E. coli* in surface waters. With respect to phenotypic tests, MAR profiles reflect the outcome of selective pressures of specific environments, and unlike genotypic tests, are very simple to implement by most water quality laboratories. MAR has displayed high utility for differentiating *E. coli* and other coliform bacteria among environments where animals and humans are exposed to different antibiotic regimes. Further research will define the optimal application and interpretation of these discriminatory tools.

Key words: *E. coli*, discriminating, DNA fingerprinting, antibiotic resistance

COLIPHAGES AS INDICATORS OF WATERBORNE ENTERIC VIRUSES

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Resource managers rely on assays of indicator microorganisms to detect fecal contamination in water. Coliform bacteria serve as the current standard, however use of these organisms does not adequately protect the public from waterborne enteric viruses. Coliphages, viruses which infect *Escherichia coli*, have been proposed as a more appropriate indicator for viral contamination. Environmental monitoring studies were conducted in a groundwater aquifer recharged with reclaimed wastewater and in impaired surface waters. The objective of these studies was to determine if a specific family or group of coliphages would act as a more reliable indicator than the somatic and male-specific groupings commonly used. Source tracking studies were also performed using F^+RNA (*Leviviridae*) coliphages. The majority of tested coliphage isolates from all six families had host ranges limited to *E. coli* strains and displayed temperature preferences up to 44.5°C, suggesting fecal origins. We propose that the standard incubation temperature for enumeration of somatic coliphages should be increased from 37°C to 44.5°C to exclusively isolate thermotolerant viruses. F^+RNA coliphages appear to be contamination-specific. Typing results suggest that contamination sources can be identified in surface water samples from which groups II (human origin), III (human origin) or IV (animal origin) F^+RNA coliphages were isolated. Group I F^+RNA coliphages appear to have both human and animal origins in the United States. These results indicate that coliphages would be valuable for routine water quality monitoring and may be of limited use for fecal source tracking.

Key Words: Coliphages, Indicators, Water Quality, Source Tracking

IDENTIFICATION OF COLIFORM POLLUTION SOURCES USING MULTIPLE ANTIBIOTIC RESISTANCE , SELECTED MOLECULAR TECHNIQUES AND GIS SPATIAL ANALYSIS

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Discharges of wastewater from sewage treatment plants (STPs), septic tanks, farm animal operations (FMOs), urbanization and wildlife pollution sources may adversely affect estuarine water quality, often closing shellfish beds for harvesting and downgrading water quality classification in rivers and streams. Development of methods for differentiating human versus wildlife coliform bacterial sources is needed to properly manage bacterial pollution emanating from different sources. Several methods for differentiating human and wildlife coliform bacterial sources were evaluated including Multiple Antibiotic Resistance (MAR), Pulsed Field Gel Electrophoresis (PFGE), and Ribotyping (RT). Water samples were collected from several river and estuarine watersheds in SC and selected pollution sources (STPs, septic tanks, FMOs, and wildlife). Samples were enumerated for fecal coliform bacterial densities (MPNs or MF) and *E. coli* were isolated by API biotyping. Samples were then analyzed by MAR, PFGE, and RT. Adjoining land use in several areas was further analyzed by GIS and multivariate statistics to predict significant land use metrics affecting fecal coliform densities and to identify human pollution sources. Results indicated that the % of *E. coli* comprising the coliform group and MAR was highest at sewage treatment plants and in urban areas adjoining sites with septic tanks or influenced by sewer discharges. Wildlife areas had negative MARs or resistance to only a single antibiotic and a lower % of *E. coli*. PFGE and RT provided DNA differentiation of bacterial pollution sources. Multivariate statistics and GIS provided methods to locate human pollution sources, identify land metrics affecting coliform MPNs and quantify presumptive Total Maximum Daily Load estimates of fecal coliform sources in shellfish harvesting areas. These findings indicate that these methods may be helpful in identifying different sources of fecal coliform bacteria.

Key Words: Multiple Antibiotic Resistance, GIS, Total Maximum Daily Loads, *E. coli*, coliform

Monitoring Coastal Ecological Processes

ANALYSIS TOOLS FOR INFERRING ECOSYSTEM PROCESS INFORMATION FROM MONITORING DATA

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Environmental monitoring programs are collecting large amounts of data describing state variables in estuarine ecosystems (e.g. salinity, DO, chlorophyll-a, nutrients, organic carbon). In contrast, cost limitations make measurements of ecosystem process rates (e.g. O_2 consumption, nutrient uptake) much less common, despite the fact that ecosystem processes can be sensitive indicators of environmental change. We have elaborated two analytical approaches, box models and open water O_2 metabolism computations, to compute extensive process information from monitoring data. Examples of process information that has been inferred from box models include: advective transport rates, turbulent mixing rates, residence times, O_2 consumption, nutrient transport, exchange, and net uptake. These rates were estimated at monthly time scales and with spatial resolution adequate to resolve regional differences within an estuary. Rates were computed for multiple years, allowing effects of river flow and other factors to be examined. Open-water metabolism computations utilized high-frequency (15 min to 1 hr.) DO, temperature and salinity records to infer daily metabolic rates for March-November. These were computed from data from the 1960's, early 1990's and late 1990's, revealing a response to changes in total nitrogen loading.

Analytical challenges and possibilities simultaneously increase with the amount of data quantifying state variables and ecosystem processes. To help analyze the often complex, non-linear, or even discontinuous interactions and associations among variables in environmental data, we are applying a tree-structured data analysis technique (CART). This algorithm is described, along with applications to submerged aquatic vegetation (SAV) habitat and zooplankton distributions in Chesapeake Bay.

Keywords: ecosystem processes, box models, open-water metabolism, nutrient transport, data analysis

VALIDATION OF THE EFFECTS OF WATERSHED DEVELOPMENT ON TIDAL CREEK SYSTEMS

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Between 1994 and 2000, a study was conducted to identify the linkages between the degree and types of watershed development and the ecological condition of tidal creeks in Charleston Harbor. Twenty-three creeks were sampled. The measurement program evaluated land cover, water quality, chemical contaminants in sediments, and the condition of biological resources. Eight creeks had forested land cover (reference). Eleven represented suburban, urban, and industrial development. Four creeks drained salt marsh vegetation: two reference creeks and two in proximity to developed regions of the Harbor. Two classes of tidal creeks (upland and salt marsh) were defined. For upland creeks, the amount of impervious surface in the watershed was associated with physical-chemical and biological conditions. When the watershed was more than 10% impervious surface, physical-chemical conditions were adversely altered. When the amount of impervious surface exceeded 30%, biological resources were degraded. Conditions in salt marsh creeks appear to reflect the conditions in the adjacent estuary. Additional creeks were sampled to validate and refine the statistical and conceptual models developed in 1994 including: 1) re-sampling six of the original creeks in 1994, 2) creeks north and south of Charleston, 3) re-sampling the original creeks in the winter 2000. The validation data suggest that the conclusions developed in 1994 were valid and have broad application. Based on this information, a monitoring approach for tidal creek systems which supplements ongoing national and regional monitoring efforts is proposed.

Key Words: tidal creeks, estuarine, impervious surfaces

PRODUCTION, RESPIRATION AND NET ECOSYSTEM METABOLISM IN U.S. ESTUARIES: EXAMPLES FROM THE NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM

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Primary production, respiration, and net ecosystem metabolism (NEM) are particularly useful indicators of ecosystem level trophic conditions within the estuaries. In this study, dissolved oxygen data collected every half hour by the National Estuarine Research Reserve System Wide Monitoring Program (January 1996 to December 1998) were used to calculate primary production, respiration, and net ecosystem metabolism. Data from two sites at each of 14 Reserves were analyzed. On average, three quarters of the data could be used to calculate metabolic rates. Temperature was the single most important factor controlling metabolic rates at individual sites, although salinity was also important at about half the sites. On an annual basis, respiration exceeded gross primary production demonstrating that at all but 4 of the 28 sites were heterotrophic. Metabolic rates were influenced by the habitat adjacent to the deployment sites. Sites near mangrove forests and in some salt marsh creeks had exceptionally high respiration rates and were exceedingly heterotrophic. Three sites, located in either eelgrass beds or above macroalgae mats, were autotrophic while one freshwater creek site was balanced. Freshwater fill time and nitrogen loading to the different estuaries could explain over 80% of the variance in net ecosystem metabolism between the different sites.

Keywords: estuary, production, respiration, net ecosystem metabolism, nutrient loading, residence time, habitat

MONITORING STRATEGIES FOR DETECTING HARMFUL ALGAL BLOOMS AND UNDERSTANDING THEIR ECOLOGY: A MULTI-INSTITUTIONAL COLLABORATION IN SOUTH CAROLINA

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The rapid rate of development in the South Carolina coastal zone has heightened public concern for the condition of the state's estuaries, and alerted scientists to the potential that novel and adverse effects on estuarine ecosystems may result. Although well-developed databases from long-term monitoring programs exist for many variables valuable in predicting and following system responses, information on phytoplankton distributions in SC estuaries has lagged. Knowledge of the dynamical relationship between environmental (e.g. turbidity, nutrient quantity and quality) and biological (e.g. bacterial competition, grazers) controls, and phytoplankton biomass and composition is critical to understanding estuarine susceptibility to eutrophication or harmful algal blooms (HABs). Over the last three years, SC scientists from federal, state, and academic institutions have developed a collaborative monitoring program to assess HAB distribution and ecology statewide. The program includes; a) intensive temporal monitoring at areas of known HAB occurrence or those exhibiting symptoms potentially related to HABs (e.g. prevalent fish lesions), b) extensive spatial monitoring in coordination with existing statewide efforts, c) a citizen volunteer monitoring network, d) nutrient response bioassays, and e) laboratory-based physiological experiments on HAB isolates. By combining "trip-wire" surveillance and rapid response systems, routine monitoring of environmental parameters and HAB distribution, and process-oriented studies examining the physiological functioning of HAB species, an enhanced understanding of the impact and environmental control of HAB in SC estuaries will be achieved. The application of this approach to studies on the distribution and physiological ecology of a new widespread red tide in SC estuaries will be described.

Keywords: development, harmful algal blooms, nutrient loading, phytoplankton, red tide

DISTRIBUTION OF NONINDIGENOUS BENTHIC SPECIES IN THE SMALL ESTUARIES OF CALIFORNIA, OREGON, AND WASHINGTON

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Nonindigenous species are a major threat to the sustainability and integrity of terrestrial and aquatic ecosystems. San Francisco Bay is the most heavily invaded water body in the United States, however, it is not clear whether other west coast estuaries are also heavily invaded. In 1999, Western EMAP sampled the benthic communities in the small estuaries in California, Oregon, and Washington (San Francisco Bay and main portions of the Columbia River and Puget Sound excluded). A total of 27 nonindigenous soft-bottom benthic species were found, which were about equally divided among polychaetes, mollusks, and crustaceans. In terms of taxonomic composition, there were relatively fewer introduced polychaete species compared to the proportion of native polychaete species, while the introduced mollusks species were over-represented. By several indicators, Oregon and Washington were at least as invaded as California. Nonindigenous species constituted 6.8%, 16.8%, and 7.1% of the individuals in California, Oregon, and Washington, respectively. Additionally, nonindigenous species occurred more frequently in Oregon and Washington, present in about 70% of the samples versus 53% in California. However, the density of nonindigenous species was higher in California. The most abundant nonindigenous species in California, Oregon, and Washington were *Streblospio benedicti*, *Hobsonia florida*, and *Streblospio benedicti*, respectively, all of which are surface-deposit feeding polychaetes. Two of the most abundant nonindigenous species in San Francisco Bay, the amphipod *Ampelisca abdita* and the bivalve *Potamocorbula*, were not found in the small estuaries.

Keywords: EMAP, nonindigenous species, estuaries, benthos, west coast

THE MYSOUND PROJECT: BUILDING AN ESTUARY-WIDE MONITORING NETWORK FOR LONG ISLAND SOUND

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In September 1998, the U.S. Environmental Protection Agency (EPA) Long Island Sound Project Office and the University of Connecticut (UConn) initiated development of a prototype marine environmental-monitoring network for Long Island Sound. The project, known as the MYSound Project (for Monitoring Your Sound), is being funded under the EPA's Environmental Monitoring for Public Access and Community Tracking (EMPACT) Program.

The goal of the project is to provide comprehensive, timely marine water-quality monitoring data on Long Island Sound and its harbors and estuaries, and to use these data as a means to increase public understanding of water quality, its importance and governing factors. The key component in the project is the establishment of an array of coastal water-quality-monitoring stations throughout the Sound. These stations use in-situ sensors and real-time data processing and telemetry to capture and transmit data to shore. The composite data set is being compiled at UConn and presented in real time on the project web site in a format that can be assimilated by project participants, stakeholders, and the public.

The project is in the third year of a three-year effort. This paper describes the current status of the project and key accomplishments in both environmental monitoring and education. It discusses how the continuous, real-time monitoring data can be used with data from other established water quality monitoring efforts to investigate issues such as hypoxia and lobster mortality in the Sound. It also describes how partnerships have been formed to expand the scope of the network and make it sustainable over the long term.

Key Words: Water Quality Monitoring, Estuarine Monitoring

EMAP Symposium Posters

CORAL DISEASE AND HEALTH CONSORTIUM: PARTNERS FOR PRESERVATION

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The Coral Disease and Health Consortium (CDHC) was one recommendation to the U.S. Coral Reef Task Force (CRTF), to conserve the coral reef ecosystems of the U.S. and its territories by preserving and protecting their biodiversity, health, heritage, and socioeconomic values (Executive Order #13089, Coral Reef Protection June 1998). The CRTF developed a National Action Plan for Coral Reef Conservation employing the CDHC as one of its action items. An interagency effort by NOAA, EPA, and DOI proposed the CDHC to organize and coordinate the scientific resources of the US and territories in order to document the condition of the ecosystem, determine causes of declines in the health, and provide technical assistance to managers regarding coral reef health. These objectives will be achieved by integrating three functional disciplines: Clinical Pathology, Health Assessment, and Risk Assessment and Management. Development of the CDHC framework already has fostered national and international partnerships in coral disease research, education, and outreach activities. Examples of products include: coral disease ID cards (NOAA); a global coral disease database (NOAA partnering with World Conservation Monitoring Center); video production highlighting coral bleaching and disease research (NOAA, EPA), and research determining the prevalence of coral disease in the Florida Keys (EPA, NOAA, and academia). The CDHC aims to significantly enhance: assessments of coral ecosystem health; improve the effectiveness of management decisions by providing early warning of disease and disease outbreaks; identify causative factors and prevention and mitigation strategies; and offer viable risk management options. NOAA, EPA, and DOI will partner with non-governmental organizations, private industry, and academia to achieve these goals.

Keywords: Coral Reefs, Coral Disease, Interagency Partners, Coral Disease & Health Consortium

SAN DIEGO COUNTY DEPARTMENT OF ENVIRONMENTAL HEALTH, THE SURFRIDER FOUNDATION AND EARTH'S 911: THE BEACH INFORMATION SYSTEM

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The County of San Diego, Surfrider and Earth's 911 have developed the Earth's 911 BEACH information system, delivering timely recreational water quality information via 1-800-CLEANUP / www.1800CLEANUP.org. The public finds out if the beach is posted, learns that water pollution involves important environmental and human health issues and is empowered with tools to help solve the problem. The beach's status, as determined by the state or local government testing agency, is delivered by an automated or browser-based process, and is immediately available via a bilingual telephone and Internet communications platform. An outreach and education campaign - applicable nationwide - will drive the general public to their community's water quality and pollution prevention information. The Earth's 911 service is provided to local communities at no cost as a "turn-key" package, allowing coastal communities to get an effective head start on public notification.

Formed as a partnership between state and local governments, USEPA, and the private sector, Earth's 911 is used by state and local agencies to deliver community-specific environmental information to the public. Earth's 911 reaches the population without regular Internet access, and the growing Spanish speaking population. The BEACH system is a cost-effective means of complying with present and future state and federal mandates, bringing the public and private sectors, nonprofits and individuals together in a partnership. It is hard to imagine a sounder opportunity to protect America's coastal recreational resources.

THE NEW BEACHES ENVIRONMENTAL ASSESSMENT AND COASTAL HEALTH ACT AND EPA'S BEACH PROGRAM

Rick Hoffmann

U.S. Environmental Protection Agency; Office of Water, Office of Science and Technology

On October 10, 2000, the Beaches Environmental Assessment and Coastal Health Act was signed into law. These are the first significant amendments to the Clean Water Act since 1987. The new law (P.L. 106-284) authorizes a national grants program to assist states and local governments implement monitoring and public notification programs for their coastal recreation waters. The law also requires that states adopt improved water quality standards and that EPA conduct studies and develop improved microbiological water quality criteria. Other requirements include development of performance criteria by EPA; establishment of programs by federal agencies; EPA public information databases; and other provisions. Mr. Hoffmann's presentation will review the key provisions of this Act.

In addition, he will discuss other aspects of EPA's Beach Program. EPA is concerned about the public health risks posed by contaminated bathing beaches. Scientific evidence from epidemiological studies as well as ongoing monitoring continue to document the potential risk of infectious diseases caused by microbial organisms in recreational waters. In response to these concerns, EPA established its BEACH program. The goal of the BEACH program is to significantly reduce the risk of disease to users of the nation's recreational waters through improvements in recreational water programs, communication, and scientific advances. The program strives to: strengthen beach programs and water quality standards; inform the public about recreational water quality; and conduct research to improve science for beach programs.

Mr. Hoffmann's presentation will review the current status of the program and how it relates to the BEACH Act.

BEFORE YOU GO TO THE BEACH...

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In 1999, states reported that 459 beaches were closed to swimming at least once because of microbial contamination. Swimmers should know about microbial contamination at beaches to minimize exposure and reduce swimming related illness. For EPAs BEACH Program, we constructed a website using MapObjects and EnviroMapper to help the public make informed decisions before going to the beach. The interactive website provides maps displaying beach locations for coastal and Great Lake beaches; advisory information; water quality data; state/local agency program descriptions and contacts; and links to time-relevant local recreational water quality data and other EPA databases.

Keywords: beaches, recreational water, monitoring, notification, EnviroMapper

AN EMAP APPROACH FOR ASSESSING THE ECOLOGICAL CONDITION OF COASTAL BEACHES

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Using the approach established by EPA's Environmental Monitoring and Assessment Program (EMAP), a pilot shoreline monitoring survey was conducted in August and September 1999, encompassing the Florida panhandle from Perdido Key, Florida to Port St. Joe, Florida. The objective of this multi-tiered survey was to develop a framework for monitoring and estimating the condition of swimmable beach areas. Thirty stations were sampled using a probabilistic sampling design. Hydrographic data was collected in addition to samples for water chemistry. Bacterial indicators, entercocci and fecal coliforms, were enumerated from the water according to the EPA Beaches Environmental Assessment Closure and Health (BEACH) Program and Florida state guidelines. Additional criteria for site condition included the presence or absence of primary and secondary dunes, anthropogenic debris and vegetation. Based on EMAP evaluation criteria and Florida state criteria, the survey indicated that the majority of Florida's panhandle beaches supported defined uses, with no more than ten percent of the area showing negetaive impacts from nutrients and bacterial contamination.

Keywords: EMAP, Monitoring, Coastal Beaches, Nutrients, Bacterial Indicators

PENSACOLA'S WEEKLY WATER QUALITY MONITORING PROGRAM

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A Weekly Water Quality Monitoring Program has been developed and implemented by the Department of Environmental Protection (FDEP) Watershed Management Section (WMS). Water samples are collected weekly from twenty high-use swimming, fishing, and boating areas in the Pensacola Bay System. Citizen volunteers assist FDEP employees with collecting the water samples. Water samples and field measurements are collected at each of the twenty sites. Field measurements include: air temperature, water temperature, dissolved oxygen, pH, and salinity. Field notes are taken to provide information on any unusual conditions. The water samples are analyzed in the DEP Northwest District's certified laboratory for: conductivity, salinity, total and fecal coliform bacteria, Enterococcus bacteria, total suspended solids, chlorophyll A & chlorophyll A uncorrected, color, nutrients, and turbidity. The results are made available to the public every week in the local newspaper and FDEP's local Internet site. The FDEP and the Escambia County Health Department coordinate to provide fecal coliform bacteria and Enterococcus bacteria results, providing a "Swimming Advisory" for sites with high bacteria results. The Water Quality Monitoring Program also allows for trend analysis to be performed. This program developed partnerships with local citizens and the local health department to enhance and coordinate monitoring efforts and provide timely and accessible results to the public. It also has served as a model for other communities concerned with the water quality of their swimming, fishing, and boating areas since its creation in 1996.

AN ON-LINE, CONTINUOUS MONITORING SYSTEM OF HYDROLOGY AND WATER QUALITY OF AN URBAN ESTUARINE ECOSYSTEM

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The Meadowlands Environmental Research Institute is developing a multimedia environmental monitoring system, measuring variables in water quality and hydrology, along with weather and air quality for the Hackensack Meadowlands District, an urban, estuarine ecosystem. The variables are measured continuously by automated sensors, with the data stored locally in electronic data loggers. Loggers have telecommunication equipment to transmit the data at specific intervals to a central computer, making some data available in near real-time. All data is stored in a database that is accessible from the Internet. The Internet interface provides data query and download capabilities.

We have a number of existing, in progress and planned applications and products to add value to this data and transform it into useful information. They include the following:
- metadata for each variable, such as units of measurement, sensor type, and accuracy;
- instant email notification when the value of a specific variable (e. g., dissolved oxygen) goes above or below a criterion value;
- automated data validation (e. g., range and rate of change checking);
- geographical depiction of flooded area, based on measured water levels and GIS topographic maps;
- prediction of peak water levels from coastal storm surge based on real-time measured water levels.

Furthermore, whereas several monitors are located in wetland restoration areas, the monitoring data will also be used to correlate environmental forcing functions such hydroperiod and water and soil salinity with floral and faunal community development, which are also being monitored.

Keywords: continuous monitoring, water quality, hydrology

WATER QUALITY MONITORING AND DATA COLLECTION IN THE MISSISSIPPI SOUND

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The United States Geological Survey and the Mississippi Department of Marine Resources are collecting data on the quality of the water in the Mississippi Sound of the Gulf of Mexico, and streamflow data for its tributaries. The U.S. Geological Survey through a cooperative agreement with the Mississippi Department of Marine Resources is collecting continuous water-level data, continuous and discrete water-temperature data, continuous and discrete specific-conductance data, as well as chloride and salinity samples at two locations in the Mississippi Sound and two Corps of Engineers tidal gages. Continuous-discharge data are also being collected at two additional stations on tributaries. The Department of Marine Resources collects water samples at 169 locations in the Gulf of Mexico. Between 1,800 and 2,000 samples are collected annually which are analyzed for turbidity and fecal coliform bacteria. The continuous data are made available real-time through the internet and are being used in conjunction with streamflow data, weather data, and sampling data for the monitoring and management of the oyster reefs and other marine species and their habitats.

Keywords: water quality monitoring, data collection

PUGET SOUND'S AMBIENT MONITORING PROGRAM – LINKS TO RESEARCH AND MANAGEMENT

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The Puget Sound Ambient Monitoring Program (PSAMP) is an interagency effort to assess the condition of Puget Sound and its resources. PSAMP's studies of the physical environment, pathogens and nutrients, toxic contaminants and biological resources are carried out by the Washington State departments of Ecology, Fish and Wildlife, Health and Natural Resources; the King County Department of Natural Resources, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service. As they present PSAMP findings, the program's scientific investigators draw conclusions about environmental problems confronting the region and make recommendations for follow up resource management actions and/or additional investigation. Through these conclusions and recommendations, the PSAMP helps to define next steps for and future needs from Puget Sound scientific inquiry. Recent PSAMP results define the emerging research and management issues. For example, research questions raised through PSAMP include:

Can we describe and measure the alteration and degradation of nearshore habitats related to the modification of Puget Sound shorelines?

What type and extent of land management practices are needed to keep fecal coliform loading to levels that will not threaten shellfish harvest in the area?

How do human-caused nutrient loadings to Puget Sound affect water quality and the Sound's biological resources?

What is the cause of increased incidence of liver lesions in English sole from Elliott Bay over the late 1990s?

These and other questions raised through PSAMP delineate issues that need to be more fully analyzed to complete the promise of linked monitoring, research and management.

Keywords: ambient monitoring, interagency monitoring, Puget Sound

MODELING SPECIES INVASIONS: NEW METHODS AND NEW DATA FROM BIODIVERSITY

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Human activities have increased the wholesale movement, either accidental or deliberate, of many species of animals and plants from one region of the planet to another. Invading species have often been able to establish populations in the new regions, many spreading successfully over large areas or achieving high abundances. Unfortunately, many of these invasive species have severely affected existing natural systems by displacing or competing with native species and altering native habitats, or by damaging agroecosystems and other human resources.

Existing strategies for combating invasive species are reactive; that is, strategies for combating an invasive species are developed only after an invasion has occurred and collateral damage has been detected. Utilizing these approaches always puts decision makers and environmental managers in a catch-up mode. A wiser approach, both biologically and economically, calls for a proactive strategy that anticipates species invasions before they occur or, at the very least, predicts which geographic areas are at maximum risk for the successful incursion and spread of potential invasive species.

A model of the ecological niche of a species can be created via comparisons between known occurrence points and ecological characteristics of the landscape. Data for these models are available for almost all species—occurrence points can be garnered from scientific specimens or observations, and electronic maps are available for many important ecological dimensions as GIS coverages. The Genetic Algorithm for Rule-set Prediction (GARP), an artificial-intelligence application, offers the most robust, and is the best tested algorithm for developing such models. Usiing GARP, the geographic locations of ecological features (both defined in latitude-longitude space) are translated into a model of suitable and unsuitable habitat in ecological dimensions. This ecological model can then be projected onto landscapes to identify areas that are suitable for that species' populations.

The existence of an ecological niche model makes possible projection of the species' distribution onto any landscape, including invaded ranges, but also including other scenarios of change, such as climate change. These maps should allow decision makers and environmental managers to make better decisions about invasive species.

Keywords: Nonindigenous species, ecological models, invasive species

DEVELOPMENT OF A DIAGNOSTIC TOOL TO DETERMINE THE CAUSE OF BENTHIC COMMUNITY DEGRADATION IN THE CHESAPEAKE BAY

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The health of benthic communities is used by environmental managers as a surrogate for the ecological health of a system. To accomplish this goal in the Chesapeake Bay, a Benthic Index of Biotic Integrity (BIBI) was previously developed. This index uses benthic community parameters and conditions at undegraded reference sites to designate areas that are degraded. For sites classified as degraded using the BIBI we developed a separate index using a discriminate analysis approach that differentiates between sediment contamination and low dissolved oxygen (LDO). Based upon past index development efforts for the Mid-Atlantic Region, 122 metrics were selected for testing. Of the metrics tested, 23 were significantly different (t-test, alpha level of 0.05) between two degraded site groups - a sediment contamination site group and a LDO affected site group. These remaining variable were further reduced in number by incrementally decreasing the accepted alpha error p value by 0.005 until the number of variables was below 18, the allowable degrees of freedom for checking assumptions of the discriminate analysis. The function correctly classified 77% of LDO affected and 80% of the sediment contamination affected sites of a separate validation data set.

Keywords: Discriminate Analysis, Benthic Index of Biotic Integrity, Chesapeake Bay, Contamination, Low Dissolved Oxygen

APPLICATION OF THE BENTHIC INDEX OF BIOTIC INTEGRITY TO ENVIRONMENTAL MONITORING IN CHESAPEAKE BAY

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The Benthic Index of Biotic Integrity (BIBI) was developed to assess benthic community health and environmental quality in estuaries. The index has been successfully applied to estuaries of the mid-Atlantic region and the southeastern United States. In the Chesapeake Bay, the application of the BIBI to environmental monitoring has been possible through a partnership among the U.S. EPA Chesapeake Bay Program, the Maryland Department of Natural Resources, and the Virginia Department of Environmental Quality. Academic institutions and the private sector facilitate this partnership. The BIBI provides Chesapeake Bay monitoring programs with an uniform tool with which to characterize bay-wide benthic community condition and assess the health of the Bay. A probabilistic-based design permits annual estimates of areal degradation within the Chesapeake Bay and its tributaries. However, of greatest interest to managers is the identification of problem areas most in need of restoration. Here we apply the BIBI to benthic data collected in the Bay since 1994 to assess benthic community degradation by Chesapeake Bay Program segment and water depth. We use a three-year moving average to assess changes over time, and discuss the merits of the method and its utility to management.

Keywords: Biological Indicators, Benthic Communities, Partnerships, Degradation, Benthic Index of Biotic Integrity, Chesapeake Bay, Contamination, Low Dissolved Oxygen

PARTNERSHIPS IN ENVIRONMENTAL MONITORING: LONG-TERM BIO-MONITORING PROGRAMS IN CHESAPEAKE BAY

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Versar has been conducting biological components of the Chesapeake Bay Monitoring Program since its inception in 1984. The long-term Zooplankton and Benthic Monitoring Programs are conducted for the Maryland Department of Natural Resources in partnership with the U.S. EPA Chesapeake Bay Program. These studies are designed to monitor consequences of bay-wide management practices using biological indicators of water quality and trend analysis of long-term data sets. The Zooplankton Monitoring Program is conducted in coordination with the Academy of Natural Sciences and the Maryland DNR. Results to date have revealed the seasonal succession of zooplankton communities within the Bay and have provided baseline data on zooplankton biomass, species composition, and distributions. These data are being used to examine the relationships between phytoplankton and water quality parameters and to assess the role of zooplankton in food webs. In the Benthic Monitoring Program, the health of benthic communities is used to establish the condition of the Bay, evaluate trends, and identify areas that may need restoration. The extent of degradation of benthic communities is determined by application of the Benthic Index of Biotic Integrity. Results have indicated that half of the Chesapeake Bay has degraded benthos. Much of this area, however, has mild degradation that should respond quickly to moderate improvements in water quality. Comparable estimates for the Maryland and Virginia portions of the Bay were enabled through a joint effort in monitoring by the two states to assess the extent of healthy tidal waters bay-wide.

Keywords: Monitoring, Zooplankton, Benthic Communities, Partnerships, Water Quality, Degradation, Benthic Index of Biotic Integrity, Chesapeake Bay

USING GIS AND ENVIRONMENTAL DATA TO IDENTIFY CRITICAL HABITAT CHARACTERISTICS FOR FINFISH AND CRUSTACEAN POPULATIONS

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Organisms inhabiting tidal creeks encounter complex natural variations in physical, chemical, and biological factors, as well as environmental degradation caused by the anthropogenic stresses of upland development. Data collected in the South Carolina Estuarine and Coastal Assessment Program (SCECAP), a joint study by the South Carolina Department of Natural Resources and the South Carolina Department of Health and Environmental Control, were used to evaluate environmental quality in tidal creek habitats throughout the state of South Carolina. Sixty tidal creeks stations were sampled in 1999 and 2000 using a probabilistic stratified-random sampling scheme. Tidal creeks were defined as all water bodies that drain vegetated wetlands and were < 100 m in width from the marsh vegetation on each shoreline. A variety of physical, chemical, biological, and geological data were measured for each tidal creek using field sampling techniques or a GIS. Specific correlative relationships between environmental parameters and diversity, abundance, and biomass of finfish and crustacean species were analyzed. Preliminary findings from multivariate statistical analyses include a positive correlation between the abundance and biomass of recreationally important finfish and the amount of habitat represented by shallow mud flats, and negative correlations between these finfish variables and the amount of open water habitat, as well as dissolved oxygen levels. Findings generated by this study will assist resource managers with a useful tool in managing finfish and crustacean populations by facilitating the identification, management, and protection of critical South Carolina tidal creek habitats.

Keywords: tidal creek, critical habitat, finfish, South Carolina

SHALLOW WATER REMOTE SENSING TECHNIQUES FOR ESSENTIAL FISH HABITAT CHARACTERIZATION

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Mapping shallow water habitats can be achieved employing various survey and analysis techniques. The intent is to maximize spatial coverage and data utility. This paper presents an overview of the techniques used to map shallow water benthic habitats in a shallow water area of Narragansett Bay, Rhode Island. The survey area encompasses approximately 500,000m^2 with depths ranging from 0-6.5 m. The purpose of this investigation is to document baseline ecological conditions, including quality and extent of eelgrass beds and substrate type, and respective community structure in a manner that permits gross changes in habitat characteristics and population to be discerned in the event of potential dredging-related impacts. Data acquisition platforms include side scan sonar, singe beam bathymetry, video transects, "planview" bottom photography, and sediment profile photography. The integration of these data types in a GIS is key to delineating Essential Fish Habitats (EFH) and other bottom types. An overview of the investigation is presented from planning to surveying and analysis. Initial results are also presented.

Key words: Habitat, GIS, EFH, dredging, community structure

EXTRACTION OF DINOFLAGELLATE DNA FROM SEDIMENT CORES AND ANALYSIS OF COMMUNITY STRUCTURE BASED ON 18S SEQUENCES

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The documented increase in the occurrence of harmful algal blooms (HAB's) worldwide has led to extensive monitoring efforts utilizing both traditional and recently developed DNA-based assay platforms. The goal of these monitoring efforts is to better define the distribution and ecology of these organisms, particularly in the context of accelerating anthropogenic environmental change. For toxin-producing HAB species of interest, such as Pfiesteria piscicida, these insights will enhance mitigation efforts. Detection of HAB (dinoflagellate) species with multiple DNA-based assays in environmental water samples has been described by our own and other laboratories. However, to fully understand the fate of cyst-forming HAB species in the water column it was necessary to develop a method for extraction of organism DNA from sediment. Here we describe a method combining centrifugation with a commercially available kit for extraction of PCR-ready dinoflagellate DNA from surface sediment and sediment cores. The method was validated and sensitivity was determined utilizing spiked sediment samples, DNA derived from sediment cores, and field application. We are utilizing this assay in conjunction with cloning and sequencing to determine community structure in sediment cores collected from Delaware Inland Bays, and from the Pocomoke and Chicamacomico Rivers (Maryland). Using this approach in parallel with pollen analyses that reflect the contemporaneous terrestrial habitat (essentially, a time line for the core), we hope to gain insights into the emergence of Pfiesteria piscicida as a HAB species in Atlantic estuarine waters.

Keywords: Pfiesteria piscicida, PCR, sediment, Chesapeake Bay

FOURTEEN-YEAR TRENDS IN THE MESOZOOPLANKTON COMMUNITIES OF THE LOWER CHESAPEAKE BAY WITH LINKAGES TO WATER QUALITY

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Zooplankton and water quality were monitored monthly in the Virginia Chesapeake Bay basin from 1985 through 1999. Long-term trends in the mesozooplankton community show a striking pattern of increasing diversity in the upper tributaries and decreasing diversity in the mainstem. This pattern of trends is accompanied by generally decreasing trends in nutrient concentrations across much of the lower Chesapeake Bay with a decrease in salinity primarily in the polyhaline segment of the Bay. Canonical analyses suggest that decreasing nutrient concentrations have contributed to the increasing mesozooplankton diversity of the tributaries. These analyses also suggest that the decreasing salinity in the mainstem is the primary factor in decreasing mesozooplankton diversity for this segment of the bay. The trend and canonical analyses together suggest that mesozooplankton diversity is a reliable indicator of nutrient enrichment in long term monitoring studies of estuaries when changes in salinity are also considered. Weak correlations of abundance with water quality parameters suggest that this component of the mesozooplanton community may be more related to predator-prey interactions that are not considered in this study.

Keywords: mesozooplankton, monitoring, diversity, water quality, long term trends, canonical analyses, Chesapeake Bay

CHESAPEAKE BAY MONITORING PROGRAM: LONG TERM PHYTOPLANKTON STUDIES IN THE SOUTHERN CHESAPEAKE BAY AND TRIBUTARIES, 1985-2000

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Since 1985, extensive monitoring of phytoplankton composition, abundance, and productivity has been in progression the southern Chesapeake Bay, and the tidal James, York, Rappahannock, and Elizabeth Rivers. Seasonal phytoplankton populations have been identified indicating a diverse flora of over 700 species, producing characteristic abundance and biomass peaks during late winter/early spring, summer, and fall months. Diatoms predominate during the spring and fall, with cyanobacteria, several phytoflagellate categories, diatoms, and a major development of autotrophic picoplankton dominant in summer. At least 13 potential toxin producers have been identified among these species (diatoms and dinoflagellates). Three annual productivity maxima are common, with an annual mean rate southward along the Bay mainstem ranging from 160.2 to 101.6 $gCm^{-3}yr^{-1}$, with higher mean annual rates near the mouths of the Rappahannock, York, and James Rivers at 176.8, 215.4, and 270.1 $gCm^{-3}yr^{-1}$ respectively. One of the highest mean annual rates was in the tidal freshwater region in the James R. at 470.6 $gCm^{-3}yr^{-1}$. There were indications of reduced light availability due to high TSS levels, as influencing the floral composition and abundance. Long term trends of variables within the system include both positive and negative patterns. In the lower Bay and these rivers, there are generally favorable and dominant diatom populations, plus chlorophytes, however, there are indications of higher cyanobacteria concentrations appearing in both the Bay and its tributaries. Supported by the Virginia Dept. of Environmental Quality and EPA.

Keywords: Chesapeake Bay, James River, Rappahannock, York River, Phytoplankton, and Productivity

MONITORING FOR PFIESTERIA AND PFIESTERIA-LIKE ORGANISMS IN THE CHESAPEAKE BAY ESTUARIES OF VIRGINIA: 1997-2000

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After an initial 1997 survey, an extensive monitoring program for Pfiesteria and Pfiesteria-like organisms (PLO) was established in Virginia estuaries plus additional analysis of waters from lower Chesapeake Bay. From 1998 through 2000, over 4800 water samples and hundreds of sediment samples were analyzed for PLO. PLO concentrations ranged between zero and 49,000 cells per ml. Samples containing PLO increased from 44.6%, and 50.1% to 72.6% from 1998 through 2000, 15.4% of the samples in year 2000 having cell concentrations >200 per.ml. The most common PLO were Cryptoperidiniopsis sp., C. broydi, Gyrodinium galatheanum, plus Gymnodinium and Gyrodinium species. PLO were more common in late spring and summer, in waters of 10-20 ppt salinity, temperatures >28°, and oxygen >6 mg per liter. PLO were common in Chesapeake Bay, being more abundant in waters above the pycnocline indicating possible input from adjacent inlets. Over 200 clonal cultures were established with many examined with SEM and used in fish bioassays to test toxicity. None to date have proven toxic to fish. Toxic strains of Pfiesteria piscicda and other PLO have been maintained in our lab for the past 2 years with their life cycle stages under study. Highest PLO concentrations were at inlets along the Potomac River and other estuaries along the Bay's western shore between the Potomac and Rappahannock Rivers. Low PLO concentrations were in the lower Bay with fewest at Atlantic coastal sites. Supported by the Virginia Departments of Health and Environmental Quality, and the Center for Disease Control and Prevention.

Keywords: Pfiesteria, Cryptoperidiniopsis, Chesapeake Bay, PLO

COASTAL DATA COLLECTION FOR THE MANAGEMENT OF SEBASTIAN INLET

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Coastal monitoring in the vicinity of the Sebastian Inlet, Florida, is sponsored by the Sebastian Inlet Tax District for use in the management of the inlet. The monitoring consists of annual aerial photographs, detailed hydrographic surveys performed semi-annually, a real-time oceanographic and meteorological data collection system, and biological surveys. These data are used to determine the physical and environmental processes occurring at the inlet and surrounding coastal area, and this information is applied to the management of the Sebastian Inlet.

Aerial photography and hydrographic surveys are performed in the inlet, on the adjacent beaches, and offshore, which document the sand movement and changes in the inlet area. Depth changes in the inlet, shoreline changes on adjacent beaches, and changes in size and movement of the ebb and flood shoals are used to determine the needs for dredging, sand bypassing, and channel location for safe navigation of the inlet.

The real-time oceanographic and meteorological data system collects wave, tide and weather data for use in determining the physical forces occurring at the inlet. This information is used as the basis for engineering designs, determining longshore sand transport, seasonal and storm impacts, and as input for hydrodynamic and sediment transport numerical models.

The Sebastian Inlet area consists of fragile estuarine and coastal ecosystems including reefs, sea grasses, and turtle nesting beaches. Monitoring of the water quality and marine life is performed regularly to assure that the operation and maintenance of the inlet avoids adverse impacts to the environment.

Keywords: inlet management, dredging, sand bypassing, coastal monitoring, aerial photography, hydrographic surveys, real-time data collection, meteorological data collection, oceanographic data collection, biological monitoring

U. S. FISH AND WILDLIFE SERVICE COASTAL PROGRAM PARTNERSHIPS AFTER THE FIRST YEAR OF EXPANSION INTO THE GREAT LAKES BASIN

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The U.S. Fish and Wildlife Service's Coastal Program focuses resources on sensitive coastal areas. The program features non-regulatory, partnership-based efforts that restore and protect habitats, enhance fish passage, and control invasive species. By applying Service funding and technical expertise to locally-led projects and leveraging the participation of other groups, the Coastal Program helps identify resource priorities and achieves on-the-ground results in a manner that would present difficulties for any single entity. A mainstay along the ocean coastlines since 1994, the program recently initiated an effort along the Nation's fourth coastline: the Great Lakes. The premier freshwater system in the world, the Great Lakes basin is home to a wide variety of fish and wildlife species with a unique assemblage of habitats. Together, with our partners, the Service undertook first year projects that focused on island habitat restoration, monitoring, invasive species control, erosion prevention along tributaries, and education. For 2001 and into the future, the Service will continue to help foster a team approach to conservation in the Great Lakes by continuing to identify common conservation goals and achieving results.

Key words: Great Lakes Basin, restoration, habitats, monitoring, invasive species, coastal, partnerships

ASSESSING THE CONDITION OF THE COASTAL RESOURCES OF PUERTO RICO: IMPLEMENTING THE COASTAL 2000 STRATEGY

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Forty-seven stations located in the coastal estuaries of Puerto Rico were sampled during the summer of 2000 using a probabilistic design. Fourteen estuaries were classified as “large” at 4.19 km^2, 25 “medium” at 3.46 km^2, and 8 “small” at 0.55 km^2. Samples were successfully collected for all indicators with the exception of fish tissue. Preliminary water column data indicates that the dissolved oxygen at all of the stations was greater than 4.2 mg/l. Surface temperatures averaged 29.6 ^oC and salinity ranged from 35 to 39 with the exception of one station in San Juan Harbor which was at 11. Water column turbidity was high with 59.6+ 14.5 % of the area sampled having less than 51 % of the ambient light striking the water surface penetrating to a depth of 1.0 meter. The application of the Coastal 2000 sampling design was successful, despite having to overcome the logistics of operating in an island territory.

Keywords: Coastal 2000, Monitoring, Estuarine Condition

COASTAL 2000 MONITORING IN THE NORTHEAST

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Coastal 2000 is a partnership between the U.S. Environmental Protection Agency and coastal states to develop a national coastal monitoring program. The Northeast portion of Coastal 2000 includes states from Delaware to Maine. This joint effort will provide a nationwide assessment. It will also permit, for the first time, regional comparisons of coastal resource conditions. Each state uses a compatible, probabilistic design and a common set of environmental indicators for water quality, sediment quality, demersal fish communities, and benthic communities. Each state will independently assess the condition of their coastal resources, yet, these estimates can be aggregated to regional and national levels. Sampling began in the summer of 2000. This poster provides details of the program plus a list of contacts for further information.

REGIONAL CITIZENS' ADVISORY COUNCILS: UNIQUE ENVIRONMENTAL MONITORING PARTNERSHIPS

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Federal legislation passed by Congress following the Exxon Valdez oil spill mandated two unique organizations that build partnerships among local communities and interest groups, government agencies, and oil industry operators in Cook Inlet and Prince William Sound (PWS), Alaska. These organizations, the PWS Regional Citizens' Advisory Council (RCAC) and the Cook Inlet RCAC, have both conducted multi-year coastal contaminant monitoring programs to determine whether nearby oil industry operations are having adverse effects on the environment. These programs provide baseline measurements of hydrocarbon levels and sources that can be used to evaluate both temporal and spatial trends.

Each RCAC has developed a program that is specific to the unique physical conditions, shoreline habitats, and contaminant sources and pathways in its geographic area. The Long-term Environmental Monitoring Program (LTEMP) conducted by the PWS RCAC has focused on analyses of aliphatic and polynuclear aromatic hydrocarbons (PAHs) in nearshore subtidal sediments and intertidal mussels (Mytilus trossulus). The Cook Inlet program was developed around a Sediment Quality Triad concept and focused on determining hydrocarbons in sediments and bivalves (mainly soft sediment species such as Macoma balthica) and determining sediment toxicity. The geographical areas of concern overlap, and both programs are conducted by consultants that use similar sampling protocols and state-of-the art analytical techniques. The data to be presented provide some of the only multi-year data for coastlines downstream of the most industrialized and populated areas in Alaska and can provide invaluable background to the EMAP program planned for coastal Alaska in 2001.

INTEGRATED ASSESSMENT OF ANTHROPOGENIC AND NATURAL CHANGES IN CHESAPEAKE BAY WATERSHEDS

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Both natural and anthropogenic factors affect spatial and temporal patterns in ecosystem conditions. To manage environmental change and risks, distinguishing between natural variations in ecosystem conditions and anthropogenic changes becomes important. This concept is illustrated using examples from Chesapeake Bay watersheds. Our analysis of historical and long-term proxy records of moisture, streamflow, and water quality variations demonstrates that anthropogenic activities during the past century have amplified environmental risks associated with natural climate variations and extremes in the Mid-Atlantic Region. Increased nitrogen loading to watersheds has meant that nitrogen flux per unit flow has increased over the past century, contributing to coastal eutrophication and Chesapeake Bay hypoxia and anoxia. A 10 % increase in precipitation over the Susquehanna watershed could translate into a 30% increase in stream flow, making it much more difficult to reduce total nitrogen fluxes from this watershed and restore environmental conditions Chesapeake Bay. Increasing water demands due to coastal urbanization have magnified the impacts of drought. The severe drought during the summer of 1999 necessitated the first ever releases of water from Jennings-Randolf and Little Seneca reservoirs specifically for the purpose of augmenting Potomac River flow. Building and development in low lying coastal areas continues, even as sea level is rising. Thus, environmental risks associated with natural wet and dry extremes of climate and anticipated climate changes are increasing. Although many uncertainties remain, a variety of actions could be taken now to reduce coastal zone risks. In parallel, additional research could help reduce key scientific uncertainties.

Keywords: Climate Variability, Climate Change, Environmental Risks, Nitrogen, Eutrophication, Drought, Potomac River, Susquehanna Watershed, Chesapeake Bay

LIVING WITH SOUTH CAROLINA'S "0.1 RULE" AND A LARGE REDUCTION IN PERMITTED LOADING

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The Total Maximum Daily Load (TMDL) for the Pee Dee River, Waccamaw River and Atlantic Intracoastal Waterway system near Myrtle Beach, South Carolina, mandated a 60-percent reduction in point source loading. Under South Carolina's water-quality standards, the permitted dischargers, within this region of the State, cannot have a cumulative impact greater than 0.1 milligram per liter of dissolved oxygen concentrations on the receiving waters. In order for municipal water-reclamation facilities to serve the rapidly growing resort and retirement community of the Grand Strand, a variable-loading scheme was developed to allow dischargers to utilize increased assimilative capacity during higher streamflow conditions while still meeting the requirements of a recently established TMDL.

As part of the TMDL development, an extensive real-time data collection network was established in the lower Waccamaw and Pee Dee River watersheds where continuous measurements of streamflow, water level, dissolved oxygen, temperature, and specific conductance are recorded. In addition, the dynamic BRANCH/BLTM models were calibrated and validated to simulate the water-quality and tidal dynamics of the system. The assimilative capacities for various streamflow conditions were also analyzed.

The variable-loading scheme established total loadings for three streamflow levels. Model simulations show the impacts from the additional loading to be less than 0.1 milligram per liter reduction in dissolved oxygen. As part of the loading scheme, the real-time network was redesigned to monitor streamflow entering the study area and water-quality conditions in the location of dissolved-oxygen "sags." The study reveals how one group of permit holders used a variable-loading scheme to implement restrictive permit limits without experiencing prohibitive capital expenditures or initiating a lengthy appeals process.

Keywords: variable-loading scheme, TMDL, water-quality model, real-time data monitoring, Pee Dee River, Waccamaw River, Atlantic Intracoastal Waterway

SAMPLE HANDLING AND LABORATORY PROCESSING OF SEDIMENT AND TISSUE SAMPLES FOR TRACE LEVEL ORGANICS ANALYSIS: COASTAL 2000 APPROACH

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Analysis of marine sediment and tissue samples for trace levels of organic contaminants requires special laboratory procedures. The high volume and diversity of samples collected as part of the Coastal 2000 program adds another level of difficulty. This presentation will describe the approach being used by Arthur D. Little, the national laboratory for the program, to meet these complex objectives.

In the laboratory, procedures are optimized in each step, from extraction, to cleanup, to instrumental analysis. The targeted organic compounds are removed from the sediment matrix by ultrasonication extraction followed by mechanical shaking to enhance recovery. Interference is removed by a combination of “clean-up” procedures, including (at minimum) sulfur removal using copper, alumina column chromatography to remove polar compounds, and size exclusion chromatography to remove large molecular weight interference.

The instruments used for the program need to be rugged and reliable, yet able to achieve low detection limits. Special tricks and “tweaks” developed by Arthur D. Little have allowed for the use of conventional environmental laboratory instrumentation. Modern advances in chromatography systems (separation columns, gas systems, computer processing) have provided additional solutions.

The volume of sample that will be handled by ADL over the course of the program is expected to exceed 2000 samples. To track the samples, each is coded and stored frozen under chain-of-custody. On the project and data management level, a computer-based information management system is used to manage samples, document sample preparation, digitally transfer instrument data, and create final hardcopy and electronic reports.

Keywords: laboratory, analysis, organics, extraction, management

USE OF RETROSPECTIVE DATA TO ASSESS ECOTOXICOLOGICAL MONITORING NEEDS FOR TERRESTRIAL VERTEBRATES RESIDING ALONG THE ATLANTIC COAST

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The Contaminant Exposure and Effects--Terrestrial Vertebrates (CEE-TV) database (www.pwrc.usgs.gov/ceetv/) contains 4,336 data records for free-ranging amphibians, reptiles, birds, and mammals residing in marine and estuarine habitat and drainages along the Atlantic Coast. These CEE-TV records were combined with watershed boundaries using GIS software in order to examine temporal and geographic trends in contaminant concentrations. Concentrations of DDE and PCBs in bird eggs were found to have decreased between 1965 and 1999, but no clear temporal patterns were observed for mercury in bird eggs or liver. Areas with high concentrations of one or more of these contaminants were still found along the Atlantic Coast. An algorithm was developed to rank the relative data needs of watersheds, incorporating the quantity of CEE-TV data within watersheds, information on water quality and watershed vulnerability to pollution, and data on federal trust properties, Superfund sites, and endangered species. Critical data gaps were identified for 48 of 278 watersheds, 23 of 90 National Wildlife Refuges, and 15 of 74 National Parks. Concentrations of DDE and PCBs in bird eggs were found to increase with decreasing water quality, indicating that organochlorine residues in eggs are potentially useful for evaluating habitat quality. Retrospective monitoring using the CEE-TV database was shown to be effective for studying contaminant exposure at large spatial scales, prioritizing areas for future field monitoring efforts, and selecting sentinel organisms. Issues encountered in this analysis highlighted the need for spatially and temporally replicated field monitoring programs utilizing random sampling to assess regional trends in contaminant exposure and effects in terrestrial vertebrates.

MAPPING BATHYMETRY AND BOTTOM TYPE IN A SHALLOW ESTUARY

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Bathymetry and bottom type are important in characterizing estuaries and their ecology but hard to map, especially in shallow estuaries. Acoustic backscattering was used to remotely sense these properties in the shallow Slocums River Estuary of Massachusetts. Acoustic pulses were transmitted and their reflections from the bottom received by a downlooking 430-kHz transducer attached to a survey vessel. The first reflection defined the depth and type of bottom below the transducer: the peak provided depth, the rising limb hardness, and the falling limb roughness. The estuary was surveyed along transects separated by 25–100 m, and at a vessel speed and a transmit/receive rate that gave a record every 4–8 m. The records were located to <1 m by a differential global positioning system. A total of 30,000 records were collected from the estuary. Hardness and roughness defined the bottom types, under the assumption that softer bottoms are smoother than harder ones. The data was classified into distinct clusters of these two variables that represented mud, sand, and rock. A global information system mapped the resulting bathymetry and bottom type over the estuary. Preliminary ground truthing supported the general characterization of the estuary.

Keywords: acoustic transducer, estuaries, mapping, bathymetry, bottom type, classification

THE SPATIAL EXTENT OF FLUVIAL INFLUENCE INFERRED FROM SeaWiFS AND RIVERINE DISCHARGE DATA

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Recently, we used a time series of satellite ocean color data to investigate the spatial extent and nature of riverine influence on coastal waters. In doing so, we capitalized on the ability of the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) to provide spatial and temporal coverage over vast areas and multi-annual time scales. It is widely known that water-leaving radiance spectra change in response to varying concentrations of dissolved and suspended constituents such as sediment, chromophoric carbon, and phytoplankton pigments. Thus, a first-order understanding of the land's influence on coastal waters can be obtained through a careful examination of the extent to which the delivery of water and its associated constituents is correlated to the time-varying spectral signature of neighboring coastal waters.

For several large rivers in North and South America, we have observed high correlations between the time series of river discharge and ocean color radiance data at pixels located near the mouth of the river. The magnitude and sign of the correlation contains information about the delivery and fate of terrigeneous materials in the ocean. The poster shows the results of this work in the regions influenced by the Mississippi and Orinoco Rivers.

Key words: ocean color, remote sensing, SeaWiFS, riverine constituents

ANTIBIOTIC RESISTANCE OF ESCHERICHIA COLI IN SOUTH CAROLINA WATERSHEDS

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The USEPA Clean water Act (1972) Section 319 mandates that bacterial pollution be reduced, or total maximum daily loads (TMDL) be developed for water bodies with historically high fecal coliform levels. In this study, surface water samples were collected from problem areas in South Carolina. Influent samples were collected from sewage treatment plants in the same areas to represent human fecal pollution. Samples were also collected from three chicken farms. Most Probable Numbers (MPNs) of fecal coliforms were determined for all surface water and sewage treatment plant samples. Presumptive Escherichia coli colonies were chosen from each site and biotyped. Confirmed E. coli isolates were analyzed for antibiotic resistance. Average MPNs from the watersheds ranged from 278-1598 fecal coliforms/100 ml. Of the 1589 presumptive E. coli colonies, at least 78% were confirmed as E. coli. Approximately 8.2% of surface water E. coli showed antibiotic resistance, while the percentage of isolates resistant to at least one antibiotic from sewage treatment plants and chicken farms were 27% and 60%, respectively. Multiple antibiotic resistance was observed in 4.6% of isolates from surface water samples, 22.8% of sewage treatment plant isolates, and 29% of chicken farm isolates. The most common antibiotic resistance pattern observed in isolates from surface water samples was to penicillin. The most common resistance pattern found in sewage treatment plant and chicken farm isolates was to tetracyclines (chlortetracycline, oxytetracycline, and tetracycline). MAR testing may be a useful tool for differentiating E. coli from anthropogenic sources versus those from non-point source pollution.

Key words: fecal coliforms, Escherichia coli, antibiotic resistance

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