



OFFICE OF RESEARCH AND DEVELOPMENT

National Health and Environmental Effects Research Laboratory

ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM (EMAP)

PROGRESS REPORT

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INTRODUCTION

PURPOSE

The *Environmental Monitoring and Assessment Program (EMAP)* is a major research program, involving each of EPA's Laboratories and Centers, EPA Regions, states, tribes, and universities. The purpose of this report is to communicate research progress in EMAP. It is not the intent of the report to discuss the findings of all EMAP partners; rather, the objective is to focus on the contributions to EMAP made by EPA's National Health and Environmental Effects Research Laboratory (NHEERL).

CONTENT

This report contains

- a summary of EMAP, including a description of the overall program, its goal and objectives, an overview of the scientific products of EMAP and where to gain access to those products, and NHEERL's Research Strategy for EMAP;
- a section that highlights recent key contributions; and
- a more detailed discussion of EMAP, by research area.

COMMENTS WELCOME

We welcome feedback. Readers with comments, questions, or requests for further information are encouraged to contact:

Mike McDonald, EMAP Director



U.S. EPA, NHEERL (MD-87)
Research Triangle Park, N.C. 27711



(919) 541-7973



mcdonald.michael@epa.gov

EMAP SUMMARY

BACKGROUND AND PROGRAMMATIC CONTEXT

Description

EMAP was created in 1988 by EPA in response to a recommendation from the Agency's Science Advisory Board (SAB). The SAB noted the need for a program to monitor the status and trends of the nation's ecological resources, maintaining that a greater understanding of the overall health of ecosystems would improve EPA's ability to identify emerging problems and avert potential environmental disasters. Such a program, it was surmised, could be used to determine the condition of ecological resources (such as estuaries or wetlands), locate regions where problems were most severe, track trends in response to environmental protection or restoration activities, and identify environmental stressors associated with negative trends. EPA could then more wisely target its dollars and research efforts toward resources at greatest risk, problems of greatest concern, and actions that provided the greatest environmental restoration gain.

Today, EMAP is a major ORD research program. It is the research cornerstone for a national monitoring network, an effort coordinated by the President's Committee on Environment and Natural Resources (CENR). Conceived as a cooperative venture that would unite the monitoring programs of multiple federal agencies across the nation, EMAP's partners now include federal agencies, state and local organizations, tribes, universities, and the scientific community at large.

EMAP is designed to help EPA answer the question, How are we doing in our efforts to protect the environment? Instead of taking the conventional single-chemical or single-site approach to environmental assessment, EMAP has adopted a comprehensive perspective to address longer-term environmental problems occurring at regional or national scales. Developing the science necessary for taking the "pulse" of the nation's resources and producing Environmental Report Cards are the driving forces behind EMAP.

NHEERL is responsible for organizing and orchestrating EMAP. A high priority is placed on research to develop tools for measuring the condition of ecological resources and on monitoring designs for detecting trends in environmental condition. These methods and concepts form the scientific underpinnings for determining the effectiveness of environmental policies and for anticipating problems before they reach crisis proportions.

By coordinating and leveraging existing monitoring programs, NHEERL and its partners are achieving much more through EMAP than would have been possible through individual monitoring programs. Thanks to EMAP research, a greater understanding of ecosystem health is being gained. In the last 10 years, EMAP has successfully developed the foundation for monitoring the status and trends of complex ecosystems, demonstrated proof-of-concept in a five-year study of the Mid-Atlantic region of the United States, and created the first nation-wide plan for assessing the status of coastal ecosystems. In the next 10 years, as it is implemented by state and local organizations, EMAP research and data will play an ever greater role in shaping environmental policy decisions.

In Support of Agency and ORD needs

EMAP research supports EPA's goal to "provide sound science to improve understanding of

environmental risk and develop and implement innovative approaches for current and future environmental problems." This goal (Goal 8) is one of 10 specified Agency goals developed in response to the Government Performance and Results Act (GPRA). Although EMAP is an ORD-wide program, its organizational home is NHEERL.

Authorizations/Mandates

EPA's authority to improve monitoring capabilities stems from its mandates to protect and preserve the biological, chemical, and physical integrity of the nation's resources. Both the Clean Air Act (CAA) Amendments and the Clean Water Act (CWA) require EPA to monitor and report on the condition of air and water, respectively. EMAP research also provides critical support for the development of biocriteria under Section 303 of the CWA.

PROGRAM GOAL AND OBJECTIVES

The *goal* of EMAP is

"to monitor the condition of the nation's ecological resources, to evaluate the cumulative success of current policies and programs, and to identify emerging problems before they become widespread or irreversible."

To achieve this goal, EMAP is developing the scientific understanding necessary for collecting environmental monitoring data so that it can be used to assess current ecological conditions and trends. This enables us to forecast future risks to the sustainability of our natural resources and to prioritize restoration efforts.

EMAP has four strategic *objectives*:

- ▶ to estimate the geographic coverage and extent of the nation's ecological resources with known statistical confidence;
- ▶ to estimate the current status, trends, and changes in selected indicators of the condition of the nation's ecological resources on a regional basis with known statistical confidence;
- ▶ to seek associations between selected stressor indicators and indicators of ecological condition; and
- ▶ to provide annual statistical summaries and periodic assessments of the nation's ecological resources.

NHEERL'S RESEARCH STRATEGY FOR EMAP

NHEERL conducts effects-based research. Our scientists develop test methods, predictive models, and scientific data that strengthen risk assessment and inform regulatory and policy decisions. EMAP research is conducted by each of our ecology divisions: the Mid-Continent Ecology Division (MED) in Duluth, MN; the Atlantic Ecology Division (AED) in Narragansett, RI; the Western Ecology Division (WED) in Corvallis, OR; and the Gulf Ecology Division (GED) in Gulf Breeze, FL.

NHEERL's EMAP research can be divided into four general categories, each of which contains several key components, briefly described below.

1. Ecological Monitoring Research

→ **Large-Scale Geographic Assessment Research**

Mid-Atlantic Integrated Assessment (MAIA). MAIA was undertaken as "proof-of-concept" research to demonstrate the scientific validity and practicality of using national environmental monitoring methods on a regional scale. The area selected for evaluation was the Mid-Atlantic region of the U.S. Information was compiled on the distribution of major stressors throughout the region (such as ozone, acid deposition, nitrogen, pesticides, etc.) and major natural resources (streams, estuaries, forests). These data were then analyzed to determine resource condition. Summaries of results are available in user-friendly State-of-the-Region reports.

EMAP Western Pilot Study. Like MAIA, the objective of the Western Pilot Study is to apply national EMAP concepts and techniques to a specific region of the U.S. Unlike MAIA, which chose an ecologically homogeneous region of the country for study, the Western Pilot will focus on an especially complex region, the West. This research, which was launched in 1999, will be the most comprehensive assessment of ecological conditions ever undertaken in the West.

→ **Coastal Monitoring Initiative**

Under the Coastal Monitoring Initiative, a single resource (coastal areas) is being studied across the United States. This research will use the tools of EMAP to provide a national snapshot of the condition of coastal areas of the U.S. Ultimately, the program will incorporate EMAP methods into State coastal monitoring programs.

→ **Biocriteria**

Biocriteria are a measure of water quality. Establishing biocriteria as an integral part of State and Tribal monitoring efforts is important to EPA's Office of Water (OW). EMAP supports biocriteria research, especially research related to the identification of reference conditions.

2. Process and Modeling Research

→ **Indicators of Ecosystem Health**

It is not practical to monitor every component of an ecosystem to determine its overall condition; instead, indicators of ecosystem health are used. Indicators provide early warning signs of ecological stress, and they can be used to detect changes in ecosystem status and monitor trends over time. NHEERL is identifying and evaluating indicators both in-house and through an extramural program (ORD's STAR program, discussed on page 8).

→ **Index Sites**

EMAP and the National Park Service have identified research sites at important locations across the U.S. for use in monitoring changing environmental conditions over long periods of time. These sites are of interest to multiple federal agencies and have some degree of environmental monitoring or effects research already in place; consequently, trends can be monitored relatively easily and with judicious use of funds.

3. Outreach and Technology Transfer

→ **Regional EMAP (R-EMAP) and Regional Intensification Sites**

These projects are designed to address problems of specific concern to the Regions. They typically tackle questions of indicator selection, sampling design, and assessment approaches, applying EMAP principles on a relatively small geographic scale.

4. Science to Achieve Results (STAR) Program

Nearly 68% of EMAP's extramural research funds support the STAR Program. Under this program, the scientific community may submit research proposals in response to Requests for Applications (RfAs) developed by NHEERL scientists and ORD's National Center for Environmental Research and Quality Assurance. The research is intended to complement NHEERL's in-house program. Several major EMAP projects are funded by the STAR program, such as Index Sites research and Regional Scaling. For more information on the STAR program and its results, please refer to <http://es.epa.gov/ncercqa/>.

SCIENTIFIC PRODUCTS AND EMAP RECOGNITION

Public Access to EMAP

EMAP's web site (<http://www.epa.gov/emap/index.html>) is the primary mechanism for linking users to EMAP data and information via the Internet. It consists of a set of linked web pages that provide access to various components of EMAP, such as research projects, a bibliography, data sets, and important news items. Usage statistics for the web site (more than 50 million hits since 1994) show a consistent broad interest in the program from the federal government, states, academia, the private sector, and environmental organizations around the world.

Scientific Publications

In its 10-year history, EMAP has produced over 1000 publications. They include over 390 peer-reviewed papers in scientific journals, seven special journal volumes, 62 book chapters, 230 publications in proceedings of technical conferences, three books on EMAP methods, 361 government publications and reports, and seven theses. These publications form the scientific foundation for the new EMAP technology. The complete EMAP bibliography is on the web page. Examples include:

- ▶ *US EPA, Office of Research and Development, An Ecological Assessment of the United States Mid-Atlantic Region, EPA/600/R-97/130, November 1997.* This atlas uses measurements derived from satellite imagery and spatial data bases to depict changing conditions across the Mid-Atlantic region of the United States.
- ▶ *Monitoring Ecological Condition at Regional Scales.* Albany, NY, April 8-11, 1997. Sandhu et al., Kluwer Academic Publishers, Boston, MA. 603 pp. This book contains the proceedings of the Third Symposium on the Environmental Monitoring and Assessment Program. It lays out the scientific direction for EMAP and discusses key research areas.
- ▶ *US EPA, Office of Research and Development, Condition of the Mid-Atlantic Estuaries, EPA/600/R-98/147, November 1998.* This report is the first in a series of State-of-the-Region Reports for the Mid-Atlantic. It breaks new ground in employing the latest scientific tools and by drawing upon carefully designed sampling plans that provide broad coverage of the Chesapeake Bay, Delaware Estuary, and Delmarva coastal estuaries.

Symposia and Workshops

EMAP has sponsored numerous symposia and workshops (27 to date) to incorporate the new technology into the monitoring infrastructure. Notable meetings include:

- ▶ *Ecological Resource Monitoring: Change and Trend Detection Workshop.* EMAP, in conjunction with the Ecological Society of America and the American Statistical Association, sponsored a workshop on trend detection in ecological systems to determine the state of the science in this area. The presentations will be published in a special issue of *Ecological Applications*, a journal published by the Ecological Society of America.
- ▶ *Statistical Issues for Monitoring Ecological and Natural Resources in the United States.* Working with the American Statistical Association's section on environmental statistics, EMAP sponsored a workshop to evaluate extant national federal monitoring programs. The working group of statisticians evaluated 12 programs. The workshop found that all federal terrestrial surveys have a strong probability design for the network, while none of the aquatic monitoring efforts, except EMAP, have this as a basis for their design.
- ▶ *American Geophysical Union (AGU) Chapman Conference on Nitrogen Cycling in Forested Catchments.* EMAP was a co-sponsor of this conference, which assembled 130 scientists from 14 countries to discuss the most recent advances in nitrogen cycling. The proceedings of the conference are being published in a special issue of an AGU peer reviewed journal.
- ▶ *The EMAP Symposium on Western Ecological Systems: Status, Issues, and New Approaches.* This three-day symposium, which attracted nearly 300 scientists, resource managers, and policy makers, focused on monitoring and assessment research, ecological indicators and monitoring designs, and ecological processes in the western U.S. The proceedings of the symposium will be published in the international journal *Environmental Monitoring and Assessment*.

Peer Review

Prior to 1995, EMAP underwent 20 peer reviews of individual components of the program as well as a program-wide review by the National Research Council. Taking into account reviewers' recommendations, an EMAP Research Strategy (EPA/620/R-98/001) was prepared in 1997. More recent peer reviews include a highly favorable review in 1998 of the EMAP Monitoring Approach by the Ecological Society of America and the American Statistical Association.

Awards

Several distinguished awards have been presented to EMAP researchers in NHEERL, including the following.

- ▶ In 1998, EMAP scientists at our Atlantic Ecology Division (Narragansett, RI) were presented EPA Bronze Medals by Region 3 for their work on *The Condition of Mid-Atlantic Estuaries* report.
- ▶ Scientists at our Atlantic Ecology Division received EPA Bronze Medals from Region 3 for their assessment of the impacts of mountain-top removal for large-scale extraction of coal.
- ▶ EMAP researchers in our Gulf Ecology Division (Gulf Breeze, FL) received an External Appreciation Recognition award from the Florida Department of Environmental Protection (the first bestowed since 1990) for assisting the Department in developing their Integrated Water Monitoring Program.

SELECTED EMAP CONTRIBUTIONS TO MAJOR ENVIRONMENTAL DECISIONS

- ➡ The State of Maryland used the EMAP publication, *An Ecological Assessment of the United States Mid-Atlantic Region: A Landscape Atlas*, during the development of the Governor's Smart Growth Initiative in 1999. The Atlas provided critical information on land cover and land use. (p. 12)
- ➡ The State of Maryland established a National Estuary Program to further protect its coastal bays based on results from the EMAP report, *Condition of the Mid-Atlantic Estuaries*. Released in 1998, this report analyzed estuarine health across the Mid Atlantic, revealing important problem areas. It was hailed as a prototype for the Vice President's "Environmental Report Card 2000." (p. 12)
- ➡ Based on MAIA research, administrators in EPA's Region 3 were able to assess the potential impacts of a new coal mining practice involving mountain-top removal and valley fill to achieve large-scale extraction of coal. They concluded that the proposed plans would increase forest fragmentation and destroy some of the most productive stream habitat in the region. (p. 12)
- ➡ A *Biological Assessment and Biocriteria Research Strategy* is in its final stages of completion and is scheduled for release in FY00. (p. 15)
- ➡ EMAP indicators, when used in our probabilistic monitoring design, have reduced monitoring costs. In one example, EMAP characterized the trophic status of northeastern U.S. lakes using only 344 lakes, a savings in both time and cost over a conventional study requiring a census of 2756 lakes. (p. 16)
- ➡ EMAP has developed and delivered a national database on 10 landscape indicators for the U.S. These indicators are being incorporated into EPA's Office of Water's National Watershed Assessment Program. (p. 17)
- ➡ A report called *Evaluation Guidelines for Ecological Indicators* is in its final stages of completion. The report, in which 15 indicator evaluation guidelines are identified, will steer the technical evaluation of indicators and facilitate indicator research and review. (p. 17)
- ➡ R-EMAP research has led to more accurate population estimates of the Oregon Coho salmon. Research showed that historic monitoring methods overestimated salmon stocks, and Oregon's fishery management program has since been restructured using an EMAP approach. (p. 19)
- ➡ A R-EMAP project in EPA Region 1 was a stunning success. The State of Maine used EMAP study design to investigate mercury contamination in its lakes and fish. Their analysis led to a state-wide fish consumption advisory. New Brunswick (Canada) also issued an advisory based on the strength of the EMAP/Maine study. (p. 19)

EMAP PROGRESS

ECOLOGICAL MONITORING RESEARCH

Issue

What are the risks posed to ecosystems by stressors (alone and in combination) over time?

Objective

Develop techniques for determining how and why a system is likely to respond to stressors and, through integrated risk assessment, enhance EPA's ability to determine whether systems respond to risk management actions as predicted.

Anticipated Impact

Strengthen forecasts of the integrated response of large-scale ecological systems to different management scenarios.

LARGE-SCALE GEOGRAPHIC ASSESSMENT RESEARCH: MID-ATLANTIC INTEGRATED ASSESSMENT (MAIA)

Background

MAIA was EMAP's first regional-scale study of environmental condition. It began as a partnership between ORD and Region 3 in 1995, and later grew to include other federal and state environmental organizations. As "proof-of-concept" research, its objective was to use the monitoring methods developed by EMAP for a regional assessment of ecological quality in the Mid-Atlantic Region of the U.S. The Mid-Atlantic stretches from southern New York to northeastern North Carolina and includes Virginia, West Virginia, Maryland, Delaware, Pennsylvania, and portions of New Jersey. Various measures of ecosystem condition from across this region were compiled and analyzed to answer the following questions:

- ▶ Is there a problem?
- ▶ Where is the problem located?
- ▶ What is causing the problem?
- ▶ Have the problems changed with time?
- ▶ What can we do about it?

Approach

Using state and federal databases in conjunction with their own monitoring research on environmental quality, NHEERL scientists compiled vast amounts of information on the condition of the ecological resources of the Mid-Atlantic region and its watersheds. Among the sources of information were the National Estuary Programs; the Chesapeake Bay Program (which has been collecting data since the late 1970s); state monitoring programs in Delaware, Maryland, and Virginia; and federal programs such as EMAP, the National Oceanic and Atmospheric Association's (NOAA) National Status and Trends Program and National Shellfish Register, and the U.S. Fish and Wildlife Service's National Wetlands Inventory. Once information was compiled, various measures of ecosystem condition were analyzed to assess status and trends in different resource categories. Fundamental issues,

such as sampling design and indicator development and testing, were addressed. The findings are being used to produce State-of-the-Region Reports, which present resource-specific environmental data in user-friendly terms. These reports will form the basis of an integrated regional "report card," a concept first proposed by Vice President Al Gore.

Major MAIA Findings

- ▶ MAIA research has provided "**proof of concept**" for large-scale monitoring, emphasizing regional-scale assessments rather than site-specific impacts. It demonstrated the integrated assessment framework, and it is setting the standard worldwide for analyzing and presenting environmental data to the public.
- ▶ The first major MAIA product was ***An Ecological Assessment of the United States Mid-Atlantic Region: A Landscape Atlas***, released in April 1998. Using satellite imagery and data collected on the ground, the Atlas describes patterns of land cover and land use across the Mid-Atlantic. The level of detail and comparability in the report has never before been achieved across such a large region. The result is an ecological "snapshot" that allows readers to visualize environmental conditions in the area. This important document helped identify vulnerable environmental areas within the region, and it was used by the State of Maryland during the development of its Governor's recent Smart Growth Initiative.
- ▶ The ***Condition of the Mid-Atlantic Estuaries*** is the first in a series of planned State-of-the-Region Reports. Hailed as a prototype for the Vice President's "Environmental Report Card 2000," this 1998 report provides the first-ever analysis of the health of 5,500 square miles of estuaries in this important geographic region. Included are such features as water quality, sediment contamination, habitat change, and the condition of living resources. Both encouraging and troubling signs were found. On the one hand, programs established to protect estuaries are having positive effects, leading to declines in nutrient levels in the Chesapeake Bay. However, the report also indicates the presence of high levels of toxic chemicals in the Delaware Estuary; declines in shellfish harvests; low dissolved oxygen in the Chesapeake Bay; and threats to coastal bays from encroaching urbanization. This report is already effecting change in the region. Based on report results, Maryland established a National Estuary Program to further protect its coastal bays.
- ▶ Results of MAIA's ***Integrated Estuarine Monitoring Program*** were featured in the Office of Water's (OW) National 305(b) Report to Congress entitled "National Water Quality Inventory - 1996 Report to Congress" (EPA-841/R-97/0008). MAIA studies were cited as an example of the direction in which aquatic monitoring should proceed. The results emphasize the role of habitat alteration as a major factor impacting the biological integrity of streams in the Mid Atlantic.
- ▶ MAIA has provided ***important insights for ecosystem management***. MAIA research showed that mountain-top forests in the Mid-Atlantic were in relatively pristine condition (<2% fragmented), supported a high level of biodiversity, and contained high-quality streams. Based on these data, regional administrators were able to address the potential impacts of a new coal mining practice involving mountain-top removal and valley fill to achieve large-scale extraction of coal. In their assessment, the proposed mining plans would not only increase forest fragmentation, they would also destroy some of the most productive stream habitat in the region.
- ▶ ***Environmental indicators*** for biology, habitat, and land activities were developed and linked with chemical and physical parameters to provide dynamic assessments of ecological

resources. More information on EMAP indicators is available on page 15.

Future Directions

A number of other MAIA reports are slated for release, including an Integrated Regional Report Card and reports on the state of streams, forests, and groundwater. MAIA also will produce a Pesticides Profile. The next phase of MAIA is the Regional Vulnerability Assessment (ReVA) project. ReVa will build on existing EMAP data and extend it into regional predictions based on the most pressing environmental problems expected over the next 5-25 years. NHEERL is developing partnerships with other Regions to adapt the MAIA experience to different geographical areas of the country, such as the West (see the Western Pilot Study described below).

LARGE-SCALE GEOGRAPHIC ASSESSMENT RESEARCH: EMAP WESTERN PILOT STUDY

Background

The first major integrated geographic pilot study to demonstrate EMAP concepts and tools on a regional scale was MAIA. But are the monitoring and assessment methods developed for the Mid-Atlantic Region applicable to other regions of the country? While the Mid-Atlantic is rather homogeneous in terms of its natural resources, the West is a much more complex region. It is a large territory with vast ecological variability (containing, for example, coastal, mountainous, and arid systems). This complexity presents a great deal of uncertainty. In this project, NHEERL will test the generalities and the core tools developed in MAIA by applying them to the West.

Approach

The Western Pilot, a cooperative venture involving 12 western states, tribal representatives, universities, and the western EPA Regional Offices (Regions 8, 9, and 10), was launched in the spring of 1999. Planned as a five-year effort to demonstrate EMAP concepts across a large and ecologically complex region, the study will focus on problems and ecosystems of critical importance to environmental decision-makers in the West. It will be the largest comprehensive study conducted by EPA on the ecological condition in this region. NHEERL's overall objectives for the study are to:

- test indicator performance (using the Ecological Indicators Guidelines) and survey designs to determine the condition of western streams and estuaries,
- collect data relative to critical regional issues, and
- establish land cover classifications for western states.

Researchers will test landscape indicators used in MAIA to determine their utility in western states, they will conduct stream surveys to confirm the existence of mapped streams and determine their health, and they will collect biological and habitat data in small estuaries with the intent of characterizing estuarine health. (This latter research is linked to the Coastal Monitoring Initiative described in greater detail in the following section.) In subsequent years, monitoring and assessment activities will be expanded to include aquatic resources in forests, deserts, mountains, and the Great Plains.

Major Western Pilot Findings

The Steering Committee for the Western Pilot has ***endorsed the overall implementation plans*** for the first year of the study. Monitoring will be conducted to determine the condition of aquatic ecological resources and to rank potential stressors.

Future Directions

Mapping and analysis of landscape indicators will continue, and a land cover atlas for the West will be produced. Researchers will evaluate landscape conditions relative to aquatic resources, and a monitoring framework for the western region will be developed for implementation by state and federal organizations.

COASTAL MONITORING INITIATIVE

Background

This program represents the first attempt ever to measure estuarine health nationwide. Though technically a stand-alone project, it is integrated into and operated in conjunction with various EMAP components, such as the Western Pilot. Incorporating EMAP monitoring methods, it is a large and comprehensive effort that is linked with state and local coastal monitoring programs around the country. Funding for coastal monitoring was received in FY2000.

Approach

This research will monitor estuarine communities along the Gulf coast, the Atlantic coastal region, and – through the Western Pilot – the Pacific coast. Efforts will be aimed at developing baseline data for trend analyses and to fill important gaps in our understanding of the aquatic health of the Nation's estuaries. The first national estuarine Environmental Report Card will be developed from this program. The report card will summarize the ecological condition, or health, of estuaries. This information will be used by EPA to track efforts to control stressors and protect these critical resources.

Major Coastal Monitoring Findings

- ▶ EMAP conducted **training sessions with four of the National Estuary Programs (NEPs)** to expand their ability to achieve monitoring goals. Local government personnel were trained to collect, analyze, and evaluate data on a variety of indicators. The training activities will be extended to all 28 NEPs as needed to incorporate these new techniques into a national coastal monitoring program.
- ▶ **Field reconnaissance** was conducted in May of 1999 for the new "probabilistically based" monitoring program for Florida, the first state to implement probability monitoring for all its natural aquatic resources. Probabilistic monitoring will allow states to fulfill their 305(b) Congressionally mandated reports on the conditions of their waters in a more cost-effective, efficient manner. The first samples are scheduled for collection in January 2000.

Future Directions

It is expected that the first marine coastal Environmental Report Card will be completed in 2001.

BIOCRITERIA

Background.

A critical part of developing biological indicators is the establishment of a standard against which the indicator may be compared to determine any deterioration in environmental condition. This baseline standard is termed a "reference" condition, and when these references are embedded within State water quality standards, they are referred to as

biocriteria. Biocriteria provide a direct measure of the condition of the aquatic community of plants and animals, and they extend the protection offered by traditional chemical criteria for aquatic life.

Approach.

EMAP research provides critical support for the development of biocriteria under section 303 of the Clean Water Act. NHEERL is assisting OW by providing sound scientific designs for determining biocriteria reference sites, assessing reference conditions by measuring the distribution and variance of biotic integrity among populations in natural waters, and improving diagnostic methods and indicators of condition.

Major Biocriteria Findings.

- ▶ A *Biological Assessment and Biocriteria Research Strategy* is in its final stages of completion and will be released in FY00.
- ▶ EMAP-sponsored research on *ecoregions* has assisted states in their assessments of biological criteria. For example, an ecoregion framework developed for the State of Tennessee, complementing its watershed assessment program, has helped in the development of biocriteria.

Future Directions.

EMAP and OW will test different approaches to establishing reference conditions for use with biocriteria in the West under the Western Pilot. This will provide an opportunity to address unanswered questions related to biocriteria and reference conditions.

PROCESS AND MODELING RESEARCH

Issue

What is the current condition of the environment, and what stressors are most closely associated with that condition?

Objective

Develop tools for monitoring ecological systems and for determining the response of ecosystems to multiple stressors at local, regional, and national scales.

Anticipated Impact

Enhance EPA's technical abilities for evaluating environmental condition and for assessing the consequences of risk management options and mitigation efforts.

INDICATORS OF ECOSYSTEM HEALTH

Background

EMAP describes indicators as characteristics of the environment that can be related to the condition of an ecological resource. They are used in monitoring programs to estimate ecological status, detect changes in ecosystem condition, identify stressor source, predict effects, and assess the effectiveness of management and policy actions. Indicators may be biological, physical, or chemical measures, an index of measures, or a model. Indicators are important tools in risk assessment, and they are central to EMAP's success. NHEERL

promotes indicator research in two ways: 1) by coordinating an intramural program and 2) by developing RfAs to stimulate academic research using funds from ORD's STAR program (discussed on page 8).

Approach

The objective of this program is to evaluate indicators for their scientific validity, relevance to ecosystem function, and responsiveness to questions of environmental value. Through this analysis, researchers determine which indicators are of immediate value to monitoring programs and which are in need of further development. Of great importance is the consistency of indicators across different spatial scales (local to regional to national) and across different levels of biological organization. EMAP measures two types of ecological indicators:

- ▶ indicators of condition, which provide quantitative estimates of the health of ecological resources (e.g., percent pollution-tolerant organisms or the number of individuals in fish communities), and
- ▶ stressor indicators, which identify characteristics of the environment that may elicit a change in the condition of ecological resources (e.g., acid deposition rates or pollutant concentrations).

Indicator development involves the study of numerous biological and ecological endpoints at multiple sampling stations. Survey techniques are often developed in order to obtain accurate field measurements. These measurements are then combined with output from predictive models to evaluate indicator performance by determining whether statistical associations exist between indicators of ecosystem condition and indicators of stress. From this information, hypotheses are formulated regarding potential causes of change. The approach recognizes that ecological resources are affected by multiple stressors capable of producing cumulative effects on entire populations and communities.

Major Indicators Findings

- ▶ The first **regional evaluation of indicators** took place in MAIA (see p. 11). This research led to the production of a Landscape Atlas for the Mid-Atlantic region, which used more than 30 indicators (e.g., population density, patterns of vegetation change) to assess watershed conditions in this region. Indicator research also led to the 1998 report *Condition of the Mid-Atlantic Estuaries* in which scientists applied the estuarine benthic index (using the condition of bottom-dwelling organisms) as one indicator of the ecological status of the Chesapeake Bay and other Mid-Atlantic estuaries.
- ▶ EMAP indicators, when used in our probabilistic monitoring design, have **reduced monitoring costs**. For example, EMAP scientists were able to characterize the trophic status of northeastern U.S. lakes using only 344 lakes, a savings in both time and cost over a conventional study requiring a census of 2756 lakes.
- ▶ EMAP has sponsored continued research on **ecoregion classifications**, which allow more efficient use of watershed indicators for environmental monitoring and assessment. These ecoregion classifications are currently in use by over 30 states in assessments of chemical, physical, and biological criteria.
- ▶ The development of a **stream habitat indicator** by EMAP researchers working on surface waters has resulted in a re-evaluation of the approach currently in use by States using OW's Rapid Bioassessment Protocols.
- ▶ EMAP research has resulted in a recommendation by EPA's OW that probability surveys

using appropriate indicators be incorporated into **State monitoring programs**. This recommendation has become part of the guidance for improving the EPA 305(b) Report to Congress.

- ▶ EMAP has developed and delivered a **national database on 10 landscape indicators** for the U.S. These landscape indicators are being incorporated into the Office of Water's National Watershed Assessment Program.
- ▶ EMAP studies, in addition to providing biological condition information, also provide data on 12 of the EPA Office of Water's 18 **national chemical/physical indicators** for water quality.
- ▶ The culmination of EMAP's work on estuarine indicators is embodied in the effect these studies have had on the **Agency's Indicator Report**. All of the Estuarine indicators were reviewed in the production of these reports, and several (Benthic Community Indices, Marine Debris Estimates, Dissolved Oxygen, Contaminants, etc.) were either used directly or offered as part of a recommended indicator.
- ▶ EMAP's **dissolved oxygen** studies in estuaries have directly affected the manner in which States, OW Programs, National Estuary Programs, and National Estuarine Research Reserves collect, analyze, and interpret dissolved oxygen information.
- ▶ A report called **Evaluation Guidelines for Ecological Indicators**, which describes guidelines for developing and evaluating indicators, is in review. Indicator development experts outside of EPA have cited the guidelines as a crucial step in assessing ecological condition.

Future Directions

NHEERL researchers will continue to test the performance of Mid-Atlantic indicators (developed as part of MAIA) using the Ecological Indicators Guidelines and will work to adapt those indicators to western ecosystems. As part of the Coastal Monitoring Initiative, there will be a push to develop and implement ecological indicators to determine the health of the nation's estuaries. Indicators of habitat suitability, landscape-level biotic processes, aquatic health, and watershed sustainability will be developed. Indicators for intensive study sites (Index Sites, below) will be incorporated into our regional surveys, and we will explore ways to link ecological health indicators and human epidemiology. Ultimately, the goal is to develop indicators that can be used to assess not only individual resources, but larger, interlinked ecological systems.

INDEX SITES

Background

In response to program reviews and the work of the CENR, EMAP is establishing research sites across the country from which to conduct intensive, long-term monitoring of ecological condition. One of our partners in this effort is the National Park Service (NPS). NPS has a history of monitoring data, and it offers a broad spectrum of ecological systems for study. Jointly, we are working to establish a set of sites that can serve as "outdoor laboratories." The goal is to create sites with consistent baseline ecological data that not only serve the particular needs of EPA and the NPS, but also provide a "magnet" for research by investigators from other agencies and institutions. Additional federal agencies will be invited to participate as the project matures.

Approach

The initial phase in this intensive network involves 14 sites located at National Parks across the country. Air monitoring is under way at each site, and additional monitoring is being initiated. The suite of stressors being monitored includes chemical contaminants (e.g., ozone, SO_x, NO_x, and metals and organics) and non-chemical stressors (e.g., UV-B radiation and climate change). Effects research will be based on known stressors at each site. For example, the TIME/LTM project will combine intensive site monitoring with regional surveys to measure response to acidic deposition in northeastern lakes. Other index site partners include the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). These agencies have joined EPA to provide standardized information on coastal ecological condition through CISNet (the Coastal Intensive Site Network), a STAR/EMAP program that will develop a network of coastal monitoring and research locations. This research will enable us to better understand coastal ecosystem processes, short-term coastal variability and long-term trends, and indicators for identifying stress and responses to stress in coastal systems across the U.S.

Major Index Site Findings

- ▶ EMAP has developed a **monitoring design** for detecting changes in aquatic effects due to acidification of surface waters. This design has been implemented by EMAP for lakes in the northeast and streams in the mid-Atlantic states.
- ▶ Research on the **effects of acid rain** found significant declines in sulfate levels (sulfate being the primary ingredient in acid rain) in many lakes and streams during the 1990s, an indication of recovery from acid rain. Because the effects were detected at large numbers of sites in many regions across North America and Europe, it was concluded that the declines resulted from environmental regulations to reduce emissions that cause acid rain.

Future Directions

Future plans include efforts to monitor stressors of soil and sediment quality and habitat quality, and to assess amphibian population declines and malformation rates in National Parks using measures of UV dosimetry.

OUTREACH AND TECHNOLOGY TRANSFER

Issue

Are EMAP's scientific products being used? Do they demonstrate scientific credibility, public acceptance and accessibility, and applicability to a variety of situations or scenarios?

Objective

Transfer EMAP techniques and approaches to the Regions, States, and Tribes.

Anticipated Impact

More rigorous and scientifically defensible approaches for use by environmental decision-makers at all levels.

REGIONAL EMAP (R-EMAP) AND REGIONAL INTENSIFICATION SITES

Background

R-EMAP partners include EMAP, EPA's Regional Offices, States, and Tribes. It is a

program that uses EMAP's broad-scale monitoring principles (i.e., its statistical sampling design and indicator concepts) to produce ecological assessments at smaller geographic scales and in shorter time frames. The objectives of R-EMAP are to

- evaluate and improve EMAP concepts for state and local use,
- assess the applicability of EMAP indicators at differing spatial scales, and
- demonstrate the utility of EMAP for resolving issues of importance to EPA Regions, States, and Tribes.

Approach

Through *R-EMAP*, all 10 Regions have the opportunity to develop and test indicators and conduct limited applications of the EMAP approach. Each EPA Regional Office can request funding for use in applying EMAP monitoring approaches to assessment problems within the regions. Research proposals are submitted to EMAP, where they undergo a competitive scientific peer review by the Laboratory. Those approved for funding receive up to \$200,000 per year. An NHEERL Ecology Division acts as sponsor, providing the funding and working with the Region in the development of the scientific design for the projects and the analysis and interpretation of data. Each Region, however, is responsible for implementing the research. The Western Regions currently have the opportunity to select certain sites as part of the Western Pilot where intensive research to acquire more information would be advantageous. These **regional intensification sites** will receive additional scrutiny using R-EMAP approaches within the broader Western Pilot context. Site examples include the Upper Missouri Basin in Region 8, the San Francisco Bay delta in Region 9, and the Colombia River basin in Region 10.

Major R-EMAP Findings

- ▶ A project in Region 1 to evaluate **mercury contamination in Maine's lakes** (and fish) has been a stunning success. The project used an EMAP probabilistic approach to sampling. Physical, chemical, and biological samples were collected from lakes, some of which had not been sampled in 15 years. Following analysis of the samples, Maine issued a state-wide fish consumption advisory. The adjacent province of New Brunswick, Canada, issued its own advisory based on Maine's results and the similarity of ecoregions. The project triggered studies in other New England states, which have since issued advisories, resulting in a comprehensive data base of lake characteristics and fish populations.
- ▶ A R-EMAP project has improved estimates of population size for **Oregon Coho salmon**. While historic, long-term monitoring of spawning suggested minimal problems with population size, salmon populations continued to decline. After using EMAP probability design, more accurate population estimates were made, and it was discovered that salmon stocks were being overestimated. These findings led to an EMAP type of monitoring approach by the Oregon fishery management program.
- ▶ Through R-EMAP efforts in Region 4, the first broad-scale descriptions of **mercury contamination throughout South Florida** (which includes the Everglades) have been obtained. A statistical EMAP survey design provided the foundation for the research, and can subsequently be used as a baseline to measure improvements in condition.
- ▶ EMAP helped initiate the federal interagency **Multi-Resolution Landscape Characterization** (MRLC) effort in 1993. EPA, USGS, and NOAA are the primary federal partners in this effort. The MRLC is producing the first nationally consistent land cover database in over 20 years at half the cost of having each agency develop its own coverages. These crucial land cover classification data bases are already available for EPA Regions 1,

2, 3, 4, 5, and 10 and will be complete for all of the contiguous U.S. early in 2000.

EMAP has provided ***extensive assistance*** in monitoring designs, indicator development, and interpretation and assessment to all 10 EPA Regions and to 27 States. In addition, EMAP has provided monitoring designs for 10 eastern European countries, Indonesia, the Russian Arctic, Brazil, Kenya, Australia, and the Scandinavian countries.

Future Directions

The next round of R-EMAP projects will be initiated in 2000 following meetings to review, select, and fund proposals.