STAR REPORT

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

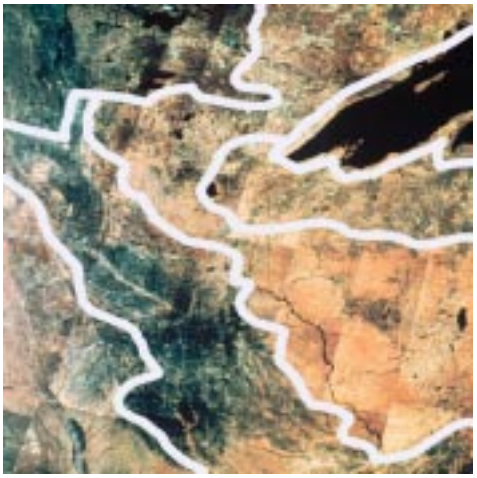
Vol.2 Issue 2 Mar. 1998 A product of the National Center for Environmental Research and Quality Assurance

ECOLOGICAL ASSESSMENT & INDICATORS RESEARCH

One of EPA's major strategic goals is to restore and maintain the health and biological diversity of ecosystems, while supporting sustainable economies and communities. However, our understanding of the interactions among the living things and habitats that make up healthy ecosystems is still limited. We lack adequate indicators and assessment approaches to characterize ecosystem health at large or small spatial scales. A good ecological indicator is a measure of one or more ecological factors that, in a repeatable and well understood way, reflects the overall "health", or integrity and sustainability, of an ecosystem.

Recognizing the need to track status and trends in the condition of the nation's ecological resources, in the late 1980s EPA established the Environmental Monitoring and Assessment Program (EMAP). EMAP supported research to identify the most scientifically defensible and cost-effective ecological indicators for ecosystems such as coastal waters, wetlands, inland waters and forests. In 1995, the National Science and Technology Council's Committee on the Environment and Natural Resources (CENR) recommended that federal agencies coordinate monitoring and research efforts to develop better national assessments. The CENR placed particular emphasis on assessment tools that would reflect conditions across ecosystems, and at various spatial scales. Indicators and assessment methods developed or refined through STAR research, together with methods developed by continuing efforts of EMAP and other federal programs, will be considered in developing future coordinated national assessments of ecological conditions, as well as for assessments at regional and watershed scales.

In 1996 and 1997, EPA's external research program, Science to Achieve Results (the "STAR program") provided funds for developing ecosystem indicators and assessment approaches to improve the ability of EPA, other agencies and scientists to focus attention where most needed in ecosystem protection and restoration programs, and to assess progress in programs already underway. The focus of the 1996 grants was "multiple scale" assessment needs. The 1997 grants focused additionally on cross-resource indicators and integrated sampling designs



STAR grants are typically awarded for three years. Final results of these projects initiated in Fiscal Years 1996 and 1997 will be presented in future reports as findings are completed and peer reviewed.

One of the major strategic objectives of EPA is to provide the scientific understanding to measure, model, maintain or restore, at multiple scales, the integrity and sustainability of ecosystems now and in the future. ..... [EPA Strategic Plan, 1997]

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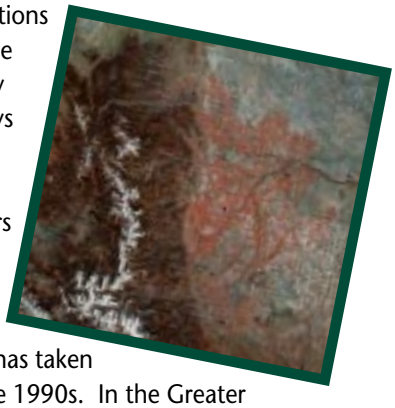
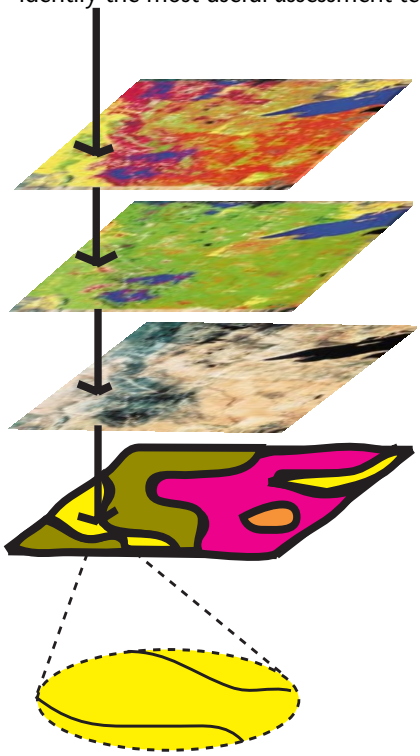
ECOLOGICAL ASSESSMENT RESEARCH IN EPA'S "STAR" PROGRAM

Multiscale Landscape Characteristics, Stresses and Ecological Impacts



To successfully manage large regional ecosystems requires broad assessments of conditions over areas that may be too expensive to monitor directly. For example, it isn't possible to use conventional sampling methods to throughly characterize ecosystem health across the many watersheds that make up large river basins. The **University of Minnesota** is developing ways to integrate satellite imagery and aerial photography with conventional ecological data for such river basins and their watersheds. They will determine the statistical variation of land alteration factors, soil geology, stream biology and other ecological data to identify indicators that best reflect natural processes and human impacts across the basin system. This very comprehensive study will provide cost-effective, statistically sound field and remotely sensed indicators applicable in many areas. **Colorado State University** is using satellite imagery to identify the most useful assessment techniques to trace ecosystem impacts as development has taken place on the Colorado Plateau from the 1970s to the 1990s. In the Greater Yellowstone Ecosystem, a team from **Iowa State University**, the **University of Oklahoma** and the **University of Kansas** will test the use of satellite data to predict habitat suitability for key terrestrial species. Field data will include butterfly, bird and plant distributions throughout the montane meadow ecosystem. The Colorado and Yellowstone studies will enhance the ability to estimate impacts of habitat alterations on wildlife, and potentially to predict which species are likely present in a region based on satellite data.



Four STAR grants focus on multiscale indicators of forest ecosystem health. The **University of Tennessee** is using study areas of three sizes: the 150 square-kilometer Oak Ridge National Laboratory Reservation, the 2000 square-kilometer Great Smoky Mountains National Park, and the approximately 150,000 square-kilometer area of the overall Southern Appalachian Region. Study factors will include topography, soil characteristics, primary productivity of land and water plants, and population characteristics of plants and wildlife such as biomass, species diversity and tree growth rates. The objective is to provide baselines against which to assess impacts of natural or human stresses such as droughts, increased nutrient deposition or land clearing, and to understand how these indicators relate to one another over areas of different sizes. The multiscale comparison will help to assess the extent to which satellite imagery can be used to infer ecological conditions in this region. A related study of baseline relationships between physical and ecological factors is being performed for the Columbia River basin by a team

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

Grants described in this report are part of EPA's Science to Achieve Results (STAR) program, a major research initiative designed to improve the quality of scientific information available to support environmental decision making. The STAR program is managed by EPA's National Center for Environmental Research and Quality Assurance in the Office of Research and Development (ORD). The program funds approximately 200 new grants every year, with the typical grant lasting three years. Funding levels vary from $50,000 to over $500,000 per year, with FY 1998 funding level at about $80 million for grants to individual principal investigators or groups of investigators. Additional STAR funds are provided for a number of Research Centers specializing in scientific areas of particular concern to EPA, and for a fellowship program supporting graduate students conducting environmental research.

led by the **University of Colorado.** Here the multi-scale assessment focuses on topography, climate, forest management and resulting impacts on land vegetation and fish abundances.

The **University of New Hampshire** is developing tree health indicators. Aspects of leaf chemistry provide indicators of stream and soil quality, air pollution, climate conditions and tree productivity. The leaf indicators will be related to satellite assessments in an effort to provide cost-effective regional assessments that combine remote sensing with "ground truth" data. **Pennsylvania State University**, the **Carnegie Museum of Natural History** and **East Stroudsburg University** are developing an index of whole ecosystem integrity for forests, based on comparing animal data to habitat quality. They are seeking an indicator useful at intermediate spatial scales, to fill the gap between stream biology indicators, used at fine scales, and the bird abundance data at regional scales. A potential intermediate scale indicator is abundance and reproductive success of a streambank bird, the Louisiana waterthrush. If the full suite of indicators accurately predicts ecosystem health, it will offer more accurate and complete status and trend assessments for the mid-Atlantic region based on integrated field and satellite data.

Ecological assessments are much needed to determine the condition of much of the areas of the western U.S. with arid and semi-arid climates. Satellite sensing is especially well suited to the vast rangeland environments. **Utah State University** is working in cooperation with private ranchers in northern Utah to take advantage of 21 years of Landsat imagery together with the ranchers' particularly complete "groundtruth" data base on ecological conditions. They are developing procedures for characterizing changes in ecosystem health associated with commercial livestock and big game animal grazing.

Indicators for Freshwater Ecosystems

The **University of Texas** has received a STAR grant to investigate the use of recent advances in aquatic bacterial ecology, nutrient chemistry and algal ecology, to develop indicators for lakes and reservoirs. The new microbial indicators are of particular interest because they are very sensitive, potentially providing early warning of ecological stress. This study will investigate whether these short term indicators adequately reflect whole-lake and larger regional responses to stresses due to excessive nutrient enrichment of watersheds.

Multiscale Research

To some extent,different measures and monitoring designs are needed for watershed, regional, national and global assessments. (Watershed-scale ecological research is supported under a "Water and Watersheds" program jointly funded by EPA's STAR program and the National Science Foundation, to be summarized in a later "STAR Report".) While watershed assessments may include fairly complete monitoring of stresses and impacts, such direct assessment is not practical over larger regions or nationally. But there are opportunities to harmonize assessments across spatial scales, by including, together with field monitoring, advanced and less expensive assessment methods based on remote sensing. Developing statistically sound sampling approaches for such multiscale assessment is a particular challenge, and procedures for integrating field data with remote sensing data for a range of ecological, hydrologic, geological and topographic conditions are critically needed.

There have been worldwide reports of deformities and local extinctions of frogs, salamanders and other amphibians, and much speculation that pollution, habitat changes or other human stresses may be the cause. Amphibians are believed to be, like the canaries used in coal mines, particularly sensitive indicators of ecological stress, in part because their skin is very permeable to contaminants. However, there have been few assessments of amphibian conditions and stressors on a regional basis. A STAR grant has been awarded to a team led by the **University of Illinois**, to assess amphibian conditions across a range of mid-western habitats. They will

Ecological Indicators Research

It is not practical to monitor all components of an ecosystem, including the water, soil, air, plants, animals, microorganisms and their interactions. Consequently, it is important to learn which ecological indicators are best used as surrogates or markers of overall ecosystem integrity and sustainability. To meet this need the STAR program supports research to develop individual indicators, or "suites" of indicators, for a range of ecosystems. Continuing the "multiscaling" emphasis from 1996, there is an emphasis on indicators that can apply across spatial scales. Also sought are indicators that may reflect impacts across types of ecosystem (e.g., fresh water, coasts, forests and grasslands), and that can be used in different monitoring designs. The following key questions are considered:

- What indicators characterize and measure ecological sustainability?
- What indicators best show changes caused by human impacts?
- How can we deal with the problem of limited data?
- How can indicators developed in one place and time be used in other places and times?

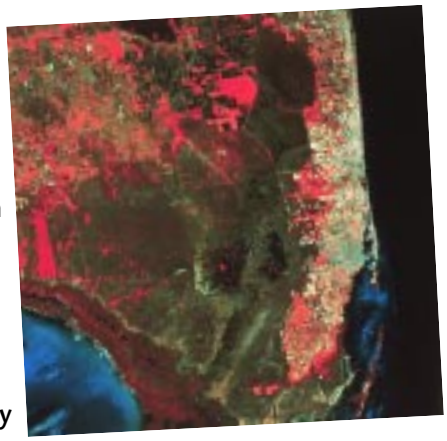
consider associations with potential stressors, including sources of pesticides and industrial chemicals, land-cover changes monitored by satellites, aquatic vegetation changes and aquatic habitat quality. If successful, this may identify amphibian condition factors to serve as early warning indicators of regional ecological stress.

Assessment for Coastal Waters and Estuaries

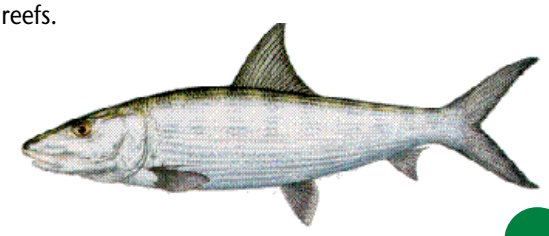
One of the most widely used indicators of the health of protected coastal waters and estuaries is the extent and condition of aquatic grasses. Healthy marsh- and seagrasses provide food, shelter and nursery areas for waterfowl, fish and food chain animals. Grasses need relatively unpolluted, clear water ro remain healthy and reproduce. Because they can be mapped using aerial photos and satellite imagery, they are a useful indicator of region-wide ecosystem conditions. But methods are needed to describe how the extent and condition of grasses relate to other indicators of ecosystem health. Several STAR grants have been awarded to develop such methods.

The **Florida International University**, **University of Southern Mississippi** and the **Florida State Department of Environmental Protection** are studying spatial scales at which sea grass condition indicators reflect impacts of natural and human stresses. The **University of Georgia** is developing practical, inexpensive methods for assessing health of salt marshes. For the ecologically unique and threatened waters of South Florida, including the Everglades and wetlands to their north, **Duke University** and the **Environmental Research Institute of Michigan** are working with the **U.S. Geological Survey** and the **National Park Service** to use satellite imagery to map fresh- and saltwater flows and inundation patterns. These are affected by land use changes and the management of water control structures. Changing flows have been major contributors to ecological damages such as noxious algal blooms and local disappearances of grasses, fish and waterfowl. This study will provide better tools to assess and predict flow patterns needed to help reduce future harm to the ecosystem.

In tropical oceans, coral condition is a key indicator of ecosystem health. Two STAR grants focus on ecological assessment for coral reefs. The **University of South Florida** is testing inexpensive "bioassays" that use microorganisms called foraminifera to determine whether coral-damaging pollution is present in natural waters. They are



also developing an index of marine ecosystem health using sediment deposits of foraminifera as pollution trend markers. In the Pacific, the **University of Guam** is developing standard protocols for assessing impacts on coral reefs from sewage, sediment runoff and pesticides. Impacts identified include serious reproductive failure of corals, eventually producing dead reefs that support little in the way of fish or other normal reef life. Products of this research will include the technical protocols and recommendations for ways to prevent and mitigate human impacts on healthy reefs.



Great Lakes Assessment Tools and Resource Management

In the 1970s, Lake Erie was severely damaged by pollution. In the 1980s, efforts by state, federal and international agencies, scientists, industry and the public resulted in successful restoration of a healthy Lake ecosystem. Pollutants from farms, industry and sewage treatment plants were greatly reduced, and water quality and fisheries recovered. However, in the 1990s, continuing and new problems, including a marked decline in the recreational walleye fishery, have arisen in Lake Erie. **Case Western Reserve University** and **Johns Hopkins University** are jointly developing new components for the Ecosystem Model that supports decision making under the Lake Management Plan. The new tools will improve the ability to explain, and perhaps decide how to mitigate, ecological and fishery impacts of habitat loss, pollution, zebra mussels, hydrologic modifications and climate change.

A significant source of toxic chemicals that cause ecological damage and require Great Lakes fisheries to be closed due to human health risks is wind-blown particles contaminated with polychlorinated biphenyls (PCBs). **Michigan State University** and the **University of Maryland** are measuring the amount of airborne PCBs contaminating fish and food webs, and comparing this to PCB releases from lake sediments. This will help to predict future trends in contamination of fish by PCBs to support developing strategies to mitigate PCB impacts.

Assessing Impacts of Ecosystem Disturbances

Urbanization has profound impacts on ecosystems. Not only are terrestrial ecosystems converted into towns and suburbs, but the ecological health of streams, rivers, lakes and coastal waters is harmed by changed water flows and pollutant runoff from construction sites, highways, homes, sewage and industrial waste. **Purdue University** is attempting to develop predictive indicators for ecological impacts in areas undergoing urban development. Such indicators would be directly useful in providing urban and regional planners with practical tools for projecting, monitoring and mitigating impacts from various development options.

Defoliation by gypsy moths can affect forest ecosystems over large areas. The **University of Maryland**, **University of Virginia** and **Oregon State University** are developing methods to relate defoliation damage and other natural and human factors that affect forest cover and tree composition to increases in nitrogen "leakage" to surface waters. Nitrogen related measures might provide practical indicators of terrestrial and aquatic impacts due to various types of forest disturbance in the mid-Atlantic region.

Find Out More About the STAR Research Program

General information on EPA's STAR research program is available from the following sources:

ORD's National Center for Environmental Research and Quality Assurance (NCERQA): Internet website: **http://www.epa.gov/ncerqa**

Mailing Address:

Office of Research and Development
National Center for Environmental Research and Quality Assurance
Office of the Director (8701 R)
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Washington, DC 20460

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STAR Research Projects Described in this Report

1996 STAR Awards

University of Georgia
Health Indicators for Salt Marsh Estuaries of the South Atlantic Bight

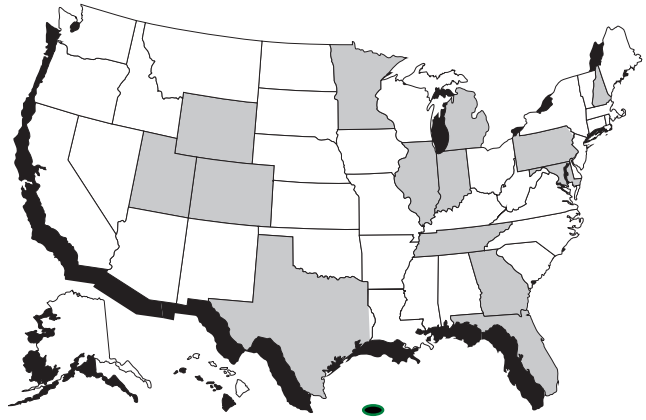
Iowa State University
Modeling Spatial and Temporal Dynamics of Montane Meadows and Biodiversity in the Greater Yellowstone Ecosystem

Florida Department of Environmental Protection; Florida International University; University of Southern Mississippi
Multiscale Assessment of the Population Status of Thalassia testudinum A New Approach to Ecosystem Assessment

Johns Hopkins University , Case Western Reserve University
Modeling and Multiobjective Risk Decision Tools for Assessment and Management of Great Lakes Ecosystems

University of Tennessee
Use of Multi-Scale Biophysical Models for Ecological Assessment Applications in the Southeastern United States

Environmental Research Institute of Michigan; Duke University
Monitoring Regional-Scale Hydrologic Processes in the South Florida Ecosystem



Colorado State University
Assessment and Analysis of Ecosystem Stressors Across Scales
Using Remotely Sensed Imagery Reducing Uncertainty in Managing the Colorado Plateau Ecosystem

University of Maryland; Michigan State University
Trophic Transfer of Atmospheric and Sedimentary Contaminants Into the Great Lakes Fisheries
Controls on the Ecosystem Scale Response Times

1997 STAR Awards

University of Guam
Development of Environmental Assessment, Mitigation and Restoration Techniques for Coral Reefs

University of New Hampshire
Foliar Chemistry as an Indicator of Forest Ecosystem Status, Primary Production and Stream Water Chemistry

Pennsylvania State University, Carnegie Museum of Natural History Powdermill Nature Reserve, East Stroudsburg University
Using Bioindicators to Develop a Calibrated Index of Ecological Integrity for a Forested Headwater Ecosystem

University of Illinois, University of Minnesota-Duluth, United States Geological Survey; Illinois Natural History Survey; and McGill University
Environmental Factors That Influence Amphibian Community Structure and Health as Indicators of Ecosystems

University of Texas at Arlington
Miicrobial Indicators of Biological Integrity and Nutrient Stress for Aquatic Systems

University of South Florida
Foraminifera as Ecosystem Indicators: Phase 1- A Marine Benthic Perturbation Index; Phase 2- Bioassay Protocols

University of Minnesota
The Development and Evaluation of Multi scale Mechanistic Indicators of Regional Landscapes

Purdue Research Foundation
Development and Evaluation of Ecosystem Indicators for Urbanizing Midwestern Watersheds

Utah State University
Characterization of the Ecological Integrity of Commercially Graded Rangelands Using Remote Sensing based Indicators

University of Maryland
Assessment of Forest Disturbance in the mid-Atlantic region: a multi-scale linkage between terrestrial and aquatic systems

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