A National Program for Monitoring Stream Condition in the Western United States

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The U.S. Environmental Protection Agency recently initiated a five-year survey of streams in the western United States as a component of the Environmental Monitoring and Assessment Program (EMAP). EMAP is developing indicators to monitor and assess the condition of ecological resources at a regional or state level of scale. This is accomplished by randomly selecting sites and by obtaining a representative sample of biotic assemblages along with physical and chemical measures. These data are then used to estimate the biological integrity of the sites. Since the stream sites are randomly selected, the data collected can be used to make regional and statewide estimates of stream condition. States included in the survey are Arizona, California, Colorado, Idaho, Montana, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. An overview of the sample design and indicator approach for stream sites sampled in Arizona, Nevada, and Utah is outlined below.

Introduction

The U.S. Environmental Protection Agency Environmental Monitoring and Assessment Program (EMAP) is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources. EMAP objectives are to advance the science of ecological monitoring and ecological risk assessment, guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics, and demonstrate an assessment framework through large regional projects.

To accomplish its goals the EMAP program has initiated a large regional study across the western United States. The primary goal of the EMAP Western Pilot Study is to generate state and regional scale assessments of the condition of ecological resources in the western United States, and to identify stressors associated with the degradation of these resources. Beginning in 1999, EMAP embarked on a five-year effort to demonstrate the application of core monitoring and assessment tools across a large geographical area of the western United States. The EMAP Western Pilot will encompass the states of EPA Regions 8, 9 and 10.

The EMAP Western Pilot Study is divided into three resource components, i.e., surface waters (lakes, streams, rivers, and wetlands), coastal systems (including estuaries), and landscapes. A probability-based sampling approach is used to monitor the ecological condition of coastal and surface waters. The landscapes component uses remotely sensed imagery and involves synoptic sampling. All three components will produce regional-scale assessments of ecological condition.

The purposes of the Surface Waters component are to:

- Describe the current ecological condition of flowing waters of the west.
- Build a database for the long-term monitoring of the west.
- Develop methodologies to advance the science of understanding the ecological function of western ecosystems and the relation of human influence.
- Work with the states and others to build a strong program of ecological monitoring that will lead to better management and protection of the waters of the west.

EMAP Sample Design

EMAP uses a statistical sampling design with three major components: the EMAP grid, a two-tier sampling approach, and a rotating sampling schedule. EMAP uses a systematic grid covering the conterminous United States, Alaska, Hawaii, and the Caribbean. The uniform spatial coverage provided by a grid ensures that each ecological resource is sampled in proportion to its geographical presence across the country. The EMAP grid consists of a set of points which, if connected, would form a series of adjacent equilateral triangles. The base density of the grid is one grid point per 635 square kilometers (a linear point-to-point distance of 27 km), resulting in 12,600 grid points in the conterminous United States. The grid's placement is determined by a formal randomization to ensure strict adherence to requirements for probability sampling. The base density can be easily intensified for subregional studies. The current EMAP sampling design for the Western Pilot Study includes approximately 1300 sites which will be sampled across the 12 states over a period of four years (325 sites/year). The sample sites for calendar year 2000 for the states of Arizona, Nevada, and Utah are displayed in Figure 1.

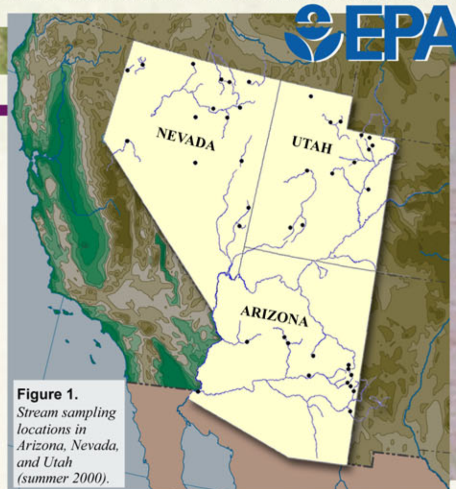

Figure 1. *Stream sampling locations in Arizona, Nevada, and Utah (summer 2000).*

Figure 2. *Measuring channel gradient.*

Ecological Indicators

A key goal of the EMAP Western Pilot is to develop local experience with a broad range of ecological indicators (fish, macroinvertebrate and periphyton assemblages; riparian and in-stream physical habitat; water chemistry). These make up the list of "core" indicators likely to be utilized both in the regionwide surveys and in smaller focus areas.

EMAP combines its statistical sampling strategy with indicators of the condition of ecological resources. Traditionally, monitoring programs have measured pollutants in the environment to determine good or poor ecological condition. EMAP takes a different approach: It examines the condition of plant and animal communities through biological and ecological indicators. This approach recognizes that ecological resources are affected by multiple stressors in all environmental media (water, air, and soil), and these stressors can produce cumulative effects on entire populations and communities. EMAP measures two types of ecological indicators:

- Condition indicators, which are characteristics of the environment that provide quantitative estimates of the state of ecological resources and that are important to society. Examples include the number of species and individuals in fish communities.
- Stressor indicators, which are characteristics of the environment that are suspected to elicit a change in the state of ecological resources. They include both natural and human-induced stressors. Examples include acid deposition rates and ambient pollutant concentrations.

Agency scientists then determine whether statistical associations exist between indicators of ecosystem condition and indicators of natural and anthropogenic stress, including stressors. Through these correlation studies, scientists can formulate hypotheses about potential causes of change for further study.

Figure 3. *Fish biometric measurements.*

Water Quality

Physiochemical water quality characteristics affect the ability of species to persist in a given lotic habitat. Water quality data are collected to determine the acid-base status, trophic condition (nutrient enrichment), and chemical stressors. Physical parameters include light penetration (e.g., turbidity, suspended solids), temperature and ionic strength (e.g., conductivity). Chemical parameters include the concentrations of dissolved gases, major cations, anions, and nutrients (i.e., nitrogen, phosphorus).

Physical Habitat Structure

Stream physical habitat structure includes all those structural attributes that influence or sustain organisms within the stream. Habitat assessments generally provide a critical understanding of a stream's ecology. Some common physical habitat attributes are stream size, channel gradient, channel substrate size and type, habitat complexity and cover, and riparian vegetation cover and structure. The understanding of the physical habitat of an area allows for better assessments of the stream ecosystem and human caused effects. *(Refer to Figure 2.)*

Aquatic Macroinvertebrate Assemblage

Aquatic macroinvertebrates play important functional roles in lotic ecosystems and are good indicators of stream quality. Aquatic macroinvertebrates represent a fundamental link in the food web between organic matter resources (e.g., leaf litter, periphyton, detritus) and fishes. Within specific biogeographical regions, aquatic macroinvertebrate assemblages respond in predictable ways to changes in stream environmental variables. Because many aquatic macroinvertebrates have limited migration patterns or a sessile mode of life, they are particularly well suited for assessing site-specific effects.

Fish and Aquatic Vertebrate Assemblage

The fish and other aquatic vertebrates can indicate stream and riparian quality. Extensive life history information is available for many species, and because many are high order consumers, they often reflect the responses of the entire trophic structure to environmental stress. Also, fish provide a more publicly understandable indicator of environmental degradation. Fish generally have long life histories and integrate pollution effects over longer time periods and large spatial scales. *(Refer to Figure 3.)*

Periphyton

Periphyton are algae, fungi, bacteria, protozoa, and associated organic matter associated with channel substrates. Periphyton are useful indicators of environmental condition because they respond rapidly and are sensitive to a number of anthropogenic disturbances, including habitat degradation, contamination by nutrients, metals, herbicides, hydrocarbons, and acidification. *(Refer to Figure 4.)*

Figure 4. *Periphyton sampling.*

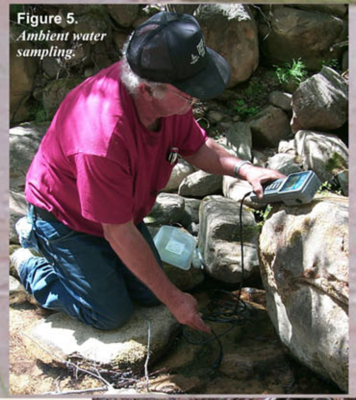

Figure 5. *Ambient water sampling.*

Figure 6. *Measuring channel morphology.*

Figure 7. *Measuring riparian habitat.*

Methods

Water Quality

Measurements of temperature, pH, conductivity, and dissolved oxygen are collected in situ. Water samples are analyzed for total alkalinity, chloride, dissolved organic carbon (DOC), ammonium, nitrate, total phosphorous (TP), and sulfate. *(Refer to Figure 5.)*

Physical Habitat Structure

The following three types of habitat variables are measured or estimated:

Continuous parameters: Thalweg profile (a longitudinal survey of depth) data and presence/absence of fine sediments are collected at either 100 or 150 equally spaced points along the stream reach. A subjective determination of the geomorphic channel type (e.g., riffle, run or glide, and pool) is made at each point. Crews also tally large woody debris along the reach. *(Refer to Figure 6.)*

Transect parameters: Measurements of channel wetted width, depth, substrate size, canopy closure, and observations of fish cover taken at 11 evenly spaced transects in each reach. Gradient measurements and compass bearing between each of the 11 stations are collected to calculate reach gradient, residual pool volume, and channel sinuosity. This category also includes measures and/or visual estimates of riparian vegetation structure, human disturbance and bank angle, incision and bank undercut. *(Refer to Figure 7.)*

Reach parameters: Channel morphology class (i.e., step-pool) for the entire reach is determined and instantaneous discharge is measured at one optimally chosen cross-section.

Aquatic Macroinvertebrate Assemblages

Two macroinvertebrate samples will be collected at each site. One will be a multi-habitat sample and the other will be a riffle sample. For the multi-habitat sample, macroinvertebrates will be collected at varying points along each of 11 transects using a D frame kick net (500 micron mesh) and composited into one sample. Sites are selected using a systematic spatial sampling design that minimizes bias in positioning the sampling stations. The riffle sample will be collected using the same gear at 4 targeted riffles and composited into one sample. Organisms are counted and identified to the finest practical taxonomic level in the laboratory. *(Refer to Figure 8.)*

Figure 8. *Sampling stream benthos.*

Fish and Aquatic Vertebrate Assemblages

The objectives of the vertebrate assemblage portion are to 1) collect all except the most rare species in the assemblage and 2) collect data for estimates of relative abundance of species in the assemblage. Fish are sampled using one-pass electrofishing in all portions of the sample reach. Fish are identified, counted, and measured. Voucher specimens are collected. Amphibians and large invertebrates (e.g., crayfish) that are captured are identified and counted only. Although these methods are not used to estimate absolute abundance, standardized collection techniques are important for consistent measures of proportionate abundance of species. *(Refer to Figure 9.)*

Periphyton

A sample is collected at each of 9 transects at the sample site. In erosional type habitats (riffles) attached periphyton is removed from substrate by brushing 12cm of substrate surface. Depositional samples are collected by removing the top centimeter of sediment from a 12cm area using a syringe. Samples are composited based on habitat type. *(Refer to Figure 10.)*

In-depth explanations of data collection methods used for the EMAP Western Pilot are available in the *Environmental Monitoring and Assessment Program-Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams (1998)* and *Western Pilot Study Field Operations Manual for Wadeable Streams (2000)*.

Figure 9. *Electroshocking for fish.*

Figure 10. *Periphyton sample processing.*

Figure 11. *EMAP field crew (left to right): B. Kepner, A. Leahy M. Hamilton, K. Leavitt, and W. Kinney.*

Summary

Currently, the majority of the data used to support decision-making efforts (i.e., water quality standards) are that of chemical data and physical data. Chemical data measure concentrations of pollutants and other chemical conditions that influence aquatic life, such as pH and dissolved oxygen concentrations. Physical data include measurements of temperature, turbidity, and solids in the water column. Traditional water quality criteria are derived from stress-response relationships and related models that predict adverse impacts when thresholds are exceeded.

Biological data measure the health of aquatic communities. Biological data include counts of aquatic species that indicate healthy aquatic conditions. Biocriteria are being incorporated into water quality standards to extend the protection offered by traditional chemical water quality criteria for non-chemical stresses to aquatic communities. While chemical and physical data may be used to predict poor and uninhabitable conditions, neither are a direct measure of ecosystem or organismal health. The multitude of interactions that can occur under varying physical and chemical conditions make it almost impossible to predict the effects of water quality on aquatic life given only physical and chemical data. Biological criteria can provide a direct measure of aquatic health.

It is anticipated that information such as that extensively gathering from the EMAP program will assist environmental managers and decision-makers in understanding stream ecological function in relation to human influence. Additionally, we expect that the EMAP monitoring data can be used to develop biological measures or indicators for ecological health and if measured over time, could be incorporated into large-scale trend assessments to determine the changing conditions of our nation's environment.

For more information:
http://www.epa.gov/emap/wpilot/

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