U.S. DEPARTMENT OF THE INTERIOR,
U.S. GEOLOGICAL SURVEY

WATER-RESOURCES NOTES

BIOLOGY AS AN INTEGRATED COMPONENT OF THE U.S. GEOLOGICAL SURVEY'S NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

U.S. GEOLOGICAL SURVEY

Open-File Report 94-83

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The U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program is designed to integrate chemical, physical, and biological data to assess the status of and trends in the Nation's water quality at local, regional, and national levels. The Program consists of 60 study units (major river basins and large parts of aquifers) located throughout the Nation (fig. 1). Data are collected at stream, river, and ground-water sites that represent the Nation's mix of major natural and human factors that influence water quality. Biological data are collected from streams and rivers, and include (1) fish and other aquatic organisms whose tissues are analyzed for a wide array of chemical contaminants; (2) characterizations of algal, benthic invertebrate, and fish communities; and (3) characterizations of vegetation growing in streams and along streambanks. These biological data are collected in conjunction with physical (streamflow, characterizations of instream, bank, and flood-plain habitats) and chemical data.

CHEMICAL VARIABLES

Information on chemical variables such as major metals and trace elements, major ions, major nutrients, and dissolved organic contaminants is collected to determine the occurrence and distribution of chemical constituents in streams, sediment, and biota. Samples are collected and processed using standard USGS methods and procedures. Chemical variables are then related to hydrologic conditions to interpret the water-resource conditions and to meet water-quality management needs such as point and nonpoint source evaluations, storm-water management, and chemical-contaminant control. To evaluate the occurrence and distribution of chemical contaminants (for example, pesticides), these contaminants are measured in the water column, the streambed sediment, and in biological tissues.

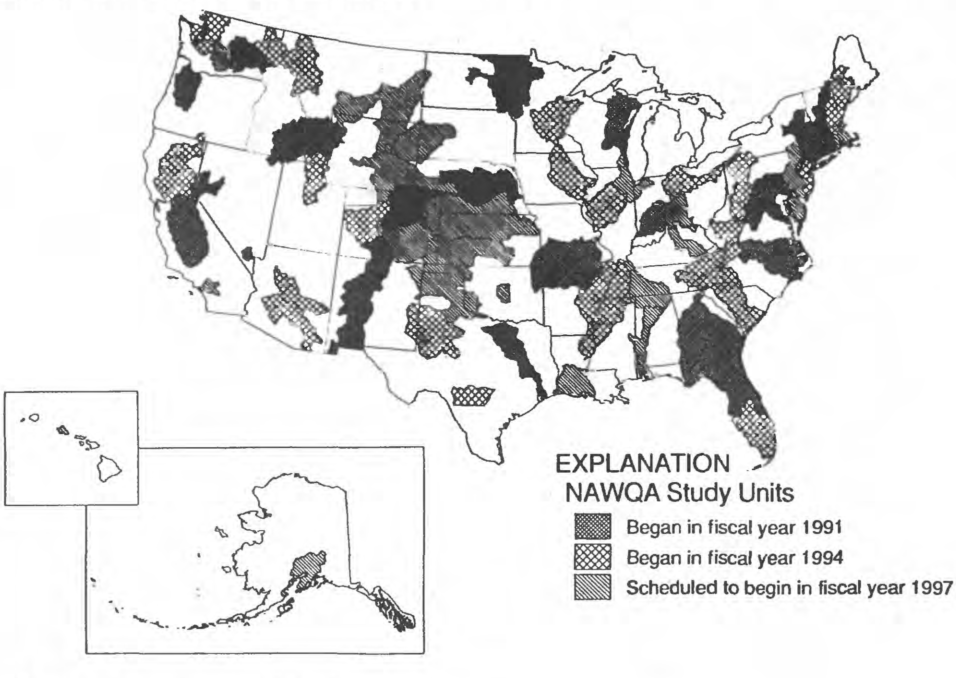

Figure 1. National Water-Quality Assessment study units.

CHEMICAL CONTAMINANTS IN BIOLOGICAL TISSUES

Biological tissues are analyzed to detect a wide array of chemical contaminants that accumulate in aquatic organisms and to provide a direct measure of the availability of these contaminants to aquatic organisms. In NAWQA, species of clams, fish, aquatic insects, and aquatic plants that are geographically widespread have been targeted for tissue analysis. Composite samples of the targeted species are analyzed for a suite of major metals and trace elements, and organic compounds. The organic compounds include organochlorine pesticides, polychlorinated biphenyls (PCB's), polynuclear aromatic hydrocarbons (PAH's) and, at a limited number of targeted sites, dioxins. Clams and whole fish are used for analyses of organic compounds. Clams, fish livers, aquatic insects, and, to a lesser extent, aquatic plants are used for analyses of major metals and trace elements. Where insufficient data exist on contaminant concentrations in sport fish, edible portions of locally important fish species are analyzed for compounds that have human consumption guidelines. Tissue data are also compared with other national data bases of contaminants in biological organisms such as the U.S. Environmental Protection Agency's National Study of Chemical Residues in Fish and the U.S. Fish and Wildlife Service's National Contaminant Biomonitoring Program.

PHYSICAL HABITAT

Habitat includes all factors that define the stream environment and its relation to aquatic organisms. Physical habitat (for example, the type of streambed material) is characterized to describe environmental settings at sites selected for water-quality assessment. Habitat characterization also provides the opportunity to examine the relative influence of changes in physical and chemical characteristics on biological communities to better interpret long-term changes in water-quality conditions.

Habitat sampling is based on a tiered design that incorporates information at basin, stream-segment, and stream-reach levels (fig. 2). Basin-level habitat data are obtained from geographic information system (GIS) data bases and include information on hydrology, climate, land use, geology, and soils. Stream-segment data are obtained from GIS data bases and topographic maps. A stream segment is defined as that part of the stream bounded by tributary junctions or major discontinuities, such as waterfalls, landform features, significant changes in gradient, or point-source discharges. Segment-level habitat data include information on stream meandering, gradient, elevation, and water-management features, such as dams, bridges, canals, or diversions. The stream reach is a part of the stream where stream, bank, and flood-plain habitat features are representative of the local area, close to the location where chemical data are collected from the water column and streambed sediment. Stream reach characterizations include information on factors such as streamflow and bank stability.

In addition to the collection of data on physical factors, biological data on instream and bank vegetation are collected at the stream reach. Instream and bank vegetation provide a critical link between aquatic and terrestrial factors that influence water quality. Transects are established perpendicular to the stream, and instream and bank vegetation species, density, and species dominance are noted along each transect.

BIOLOGICAL COMMUNITIES

Biological communities, including algal, fish, and benthic invertebrate communities, will be assessed by NAWQA. Biological community surveys are one of the few means of directly assessing the biological integrity of a site and the only approach that is sensitive to changes in water chemistry and changes in physical habitat. Therefore, biological community surveys are an essential component of any water-quality assessment.

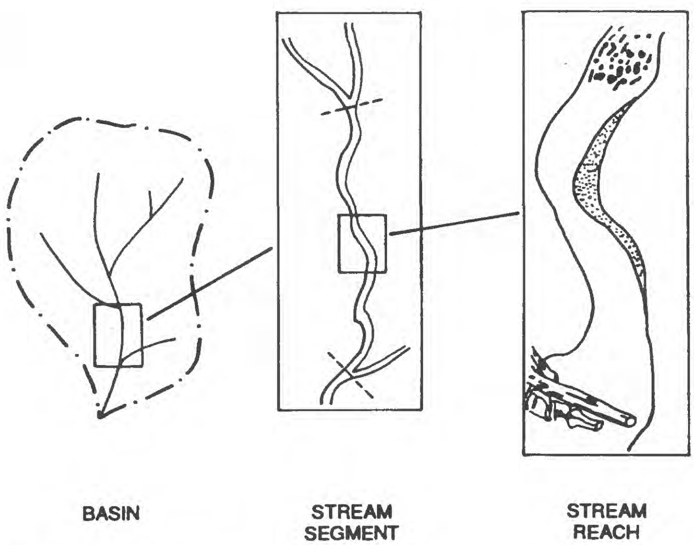

Figure 2. Spatial hierarchy of basin, stream segment, and stream reach.

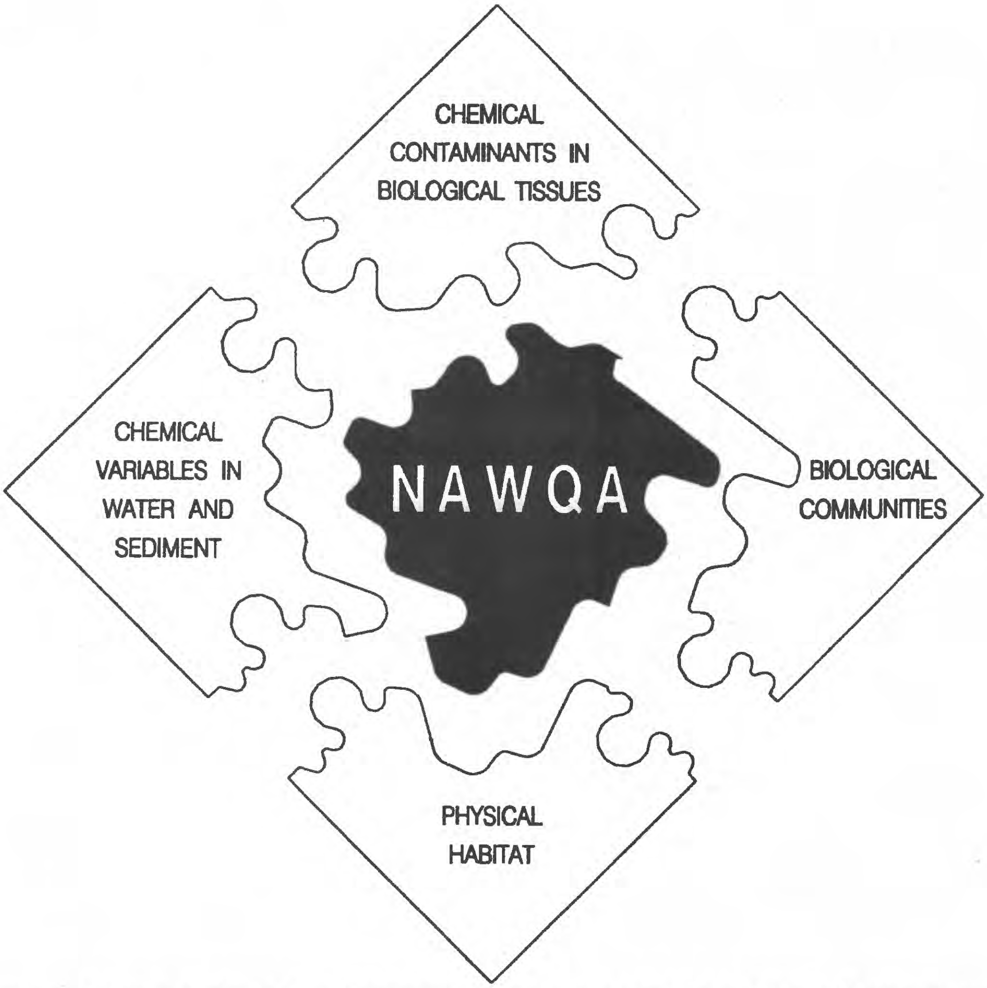

Figure 4. Integration of chemical, physical, and biological components in the National Water-Quality Assessment Program.

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Algae

Algae and phytoplankton respond relatively quickly (within days to weeks) to changes in their environment, and thus serve as valuable biological indicators of relatively rapid changes in water-resource conditions--for example, nutrient concentrations, pH, and salinity. The species distribution and community structure of algae and phytoplankton are characterized within the stream reach using a combination of quantitative and qualitative methods. Quantitative samples of algae are collected from natural stream substrates using the sampling method that is most appropriate for a particular algal substrate (for example, submerged rocks or logs). Qualitative samples of algae and aquatic mosses from available substrates in the stream reach supplement the quantitative samples by providing lists of taxonomic groups present in the stream reach at the time of collection.

Benthic Invertebrates

Benthic invertebrates (aquatic insects, molluscs, crustaceans, and worms) are important indicators of water-quality conditions because of their association with streambed substrates and their life cycles (from months to a few years), which are intermediate between fish and algae. Benthic invertebrates can also be used to characterize changes in water quality over a relatively small spatial area in contrast with fish, which can travel long distances. Benthic invertebrate community structure is characterized for the stream reach using a combination of quantitative and qualitative methods. Quantitative samples of benthic invertebrates are collected from specific types of substrate within the stream reach (for example, rocks or woody debris) to measure community structure, expressed as relative abundance of each taxonomic group. Qualitative samples of benthic invertebrates from all types of substrate throughout the stream reach are collected to supplement quantitative samples in developing lists of taxonomic groups present within the stream reach at the time of collection.

Fish

Fish communities integrate the effects of changes on other components of the environment, such as chemical and physical variables, algae, and benthic invertebrates, because of their dependence on these components for reproduction, survival, and growth. Because fish are relatively long lived (years to decades), they are valuable biological indicators of long-term water-resource conditions. In addition, understanding the relation between fish community structure and water-resource conditions is important because of the economic value and public interest that fish generate. Representative samples of the fish community are collected from the stream reach using a combination of sampling methods to determine species presence and relative abundance. The two primary sampling methods used are electrofishing (fig. 3) and seining. Fish are identified to species, length and weight are recorded, and the presence of external anomalies, including skeletal deformities, eroded fins, lesions, tumors, diseases, and parasites, is noted.

DATA STORAGE AND ANALYSIS

Chemical, physical, and biological data will be stored in an integrated data base--National Water Information System-II (NWIS-II). Data analyses consist of descriptive summarizations of biological information, such as contaminant concentrations and taxonomic lists, numbers of species, and descriptions of aquatic communities (such as species diversity); and statistical analyses. Statistical techniques are used to examine spatial patterns and temporal trends in the relations among chemical, physical, and biological components. Data can be used for calculating multimetric indexes (for example, the Index of Biotic Integrity) in study units where appropriate. Results are provided in interpretive reports covering individual study units and regional and national assessments.

Figure 3. Backpack electrofishing on Woodland Creek, Ulster County, New York.

INTEGRATION

The design of the NAWQA Program focuses on the integration of key chemical, physical, and biological data (fig. 4) to improve understanding and interpretation of the natural and human factors that affect the quality of the Nation's water resources. Thus, biological data serve a critical role as an integrated component of the NAWQA Program because they provide one of the important multiple lines of evidence (chemical, physical, and biological) for describing the status of and trends in water quality. By linking these components of water quality at various spatial scales, the NAWQA Program will provide the kinds of information needed to generate policies and management actions that improve the Nation's water resources.