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The Quality of Our Nation's Waters

Ecological Health in the Nation's Streams

Aquatic biological communities, which are collections of organisms, are a direct measure of stream health because they indicate the ability of a stream to support life. This fact sheet highlights selected findings of a national assessment of stream health by the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS). The assessment was unique in that it integrated the condition of three biological communities—algae, macroinvertebrates, and fish—as well as measures of streamflow modification, pesticides, nutrients, and other factors. At least one biological community was altered at 83 percent of assessed streams, and the occurrence of altered communities was highest in urban streams. Streamflows were modified at 86 percent of assessed streams, and increasing severity of streamflow modification was associated with increased occurrence of altered biological communities. Agricultural and urban land use in watersheds may contribute pesticides and nutrients to stream waters, and increasing concentrations of these chemicals were associated with increased occurrence of altered biological communities.

At least one biological community—algae, macroinvertebrates, or fish—was altered in 83 percent of assessed streams.

The occurrence of altered biological communities was higher in urban than agricultural settings (89 percent versus 79 percent of assessed sites, fig. 1). All three communities—algae, macroinvertebrates, and fish—were altered in 22 percent of assessed streams. A biological community was classified as altered at a stream site if the numbers and types of organisms in it were substantially different from its natural potential as estimated from regional reference sites. The high occurrence of altered communities suggests that stream health is threatened by a wide variety of land and water use across the Nation.

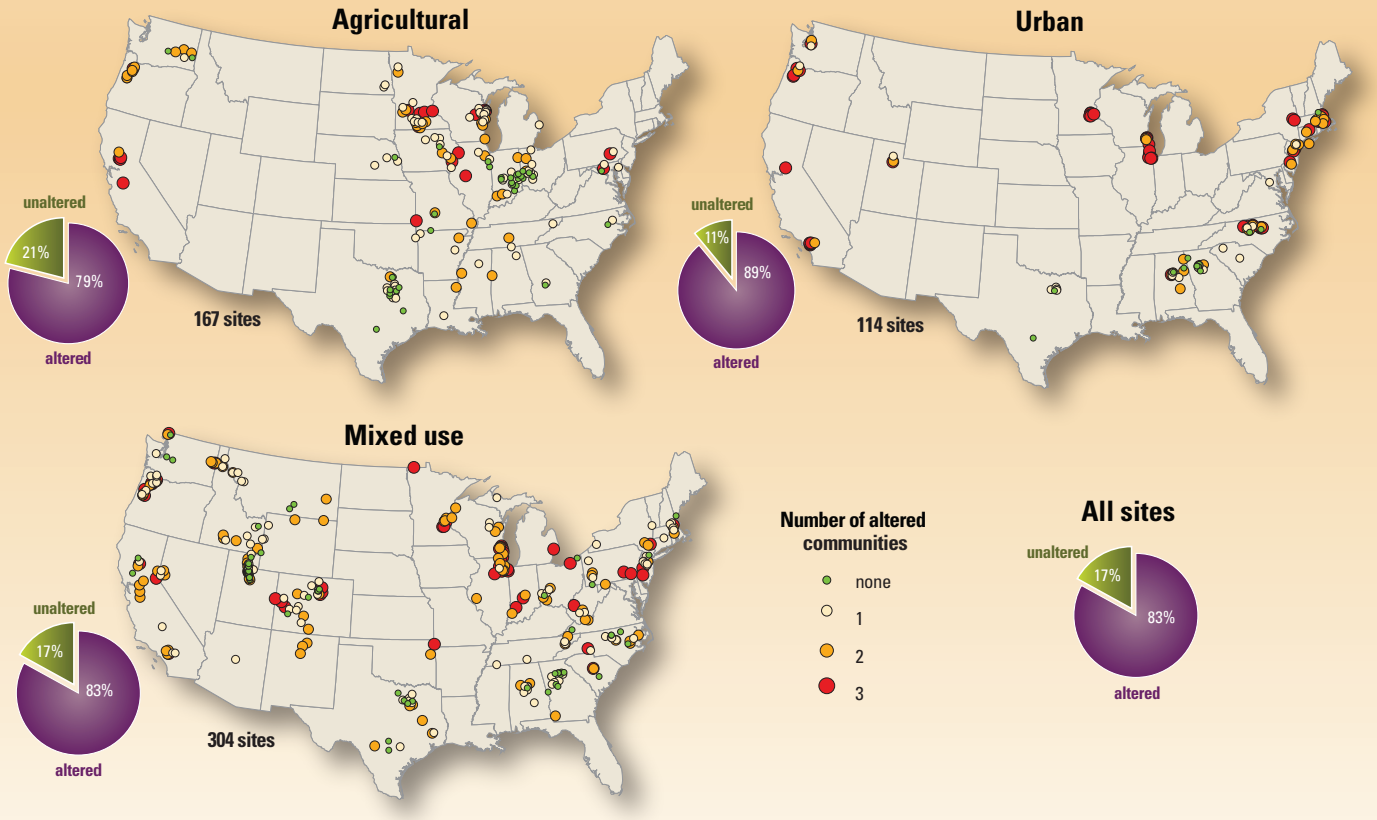


Figure 1. Regardless of the land-use setting, at least one biological community was altered, relative to regional reference conditions, at 83 percent of the streams where integrated assessments of algal, macroinvertebrate, and fish communities were conducted.

Unaltered biological communities were present in 17 percent of assessed streams.

The presence of unaltered biological communities in agricultural and urban watersheds suggests that it is possible to maintain stream health despite substantial human activities in a watershed. Within each land-use setting, altered biological communities varied widely in the degree to which they differed from their natural potential. This finding suggests that the effects of agricultural and urban land use on stream health are not uniform across the Nation, but depend on factors such as local land-use practices, climate, and topography.

Assessments limited to a single biological community are likely to underestimate the influence of land and water use on stream health.

Integrated assessments of algal, macroinvertebrate, and fish communities revealed twice as many altered streams in agricultural and mixed-use settings compared to single-community assessments. Multicommunity assessments increase the likelihood of detecting reduced stream health because species in different communities have unique vulnerabilities to manmade changes in their physical and chemical surroundings.

Reduced stream health is associated with manmade modifications to physical and chemical factors that often result from land and water use.

Maintenance of stream health requires that physical and chemical properties of streams remain within the bounds of natural fluctuations. Many naturally occurring species have low tolerances to changes in their physical or chemical environment. When physical and chemical properties of streams are shifted beyond their natural ranges, vulnerable species may be eliminated, ultimately reducing stream health.

Manmade modifications to key physical and chemical factors that control stream health are extensive, occurring in all types of land-use settings. Recent assessments by NAWQA, the U.S. Environmental Protection Agency, State agencies, and others have documented the importance of habitat modification, chemical contaminants, and nonnative species in reducing stream health across the Nation. This fact sheet focuses on the importance of modified flows, excess nutrients, and pesticides to the health of streams and rivers.

Streamflow Modification

Annual high or low flows were modified in 86 percent of the streams assessed across the Nation (fig. 2). Natural fluctuations of flows are critical to stream health because they build and maintain physical habitats, influence physical and chemical characteristics of water, and provide important life-stage cues for aquatic organisms. Streamflows are modified by a variety of land- and water-management activities, including reservoir storage and releases, stream diversions, subsurface tile drainage, groundwater withdrawals, wastewater inputs, and removal of vegetated land cover in the watershed.

Biological communities were altered more frequently in streams with modified flows. The occurrence of altered fish communities increased 12–40 percent in streams with increasing severity of depleted high flows (fig. 3). This association between biological alteration and streamflow modification was evident even after controlling for the influence of other factors that affect biological communities, such as nutrients, salinity, and land cover (Carlisle and others, 2010).

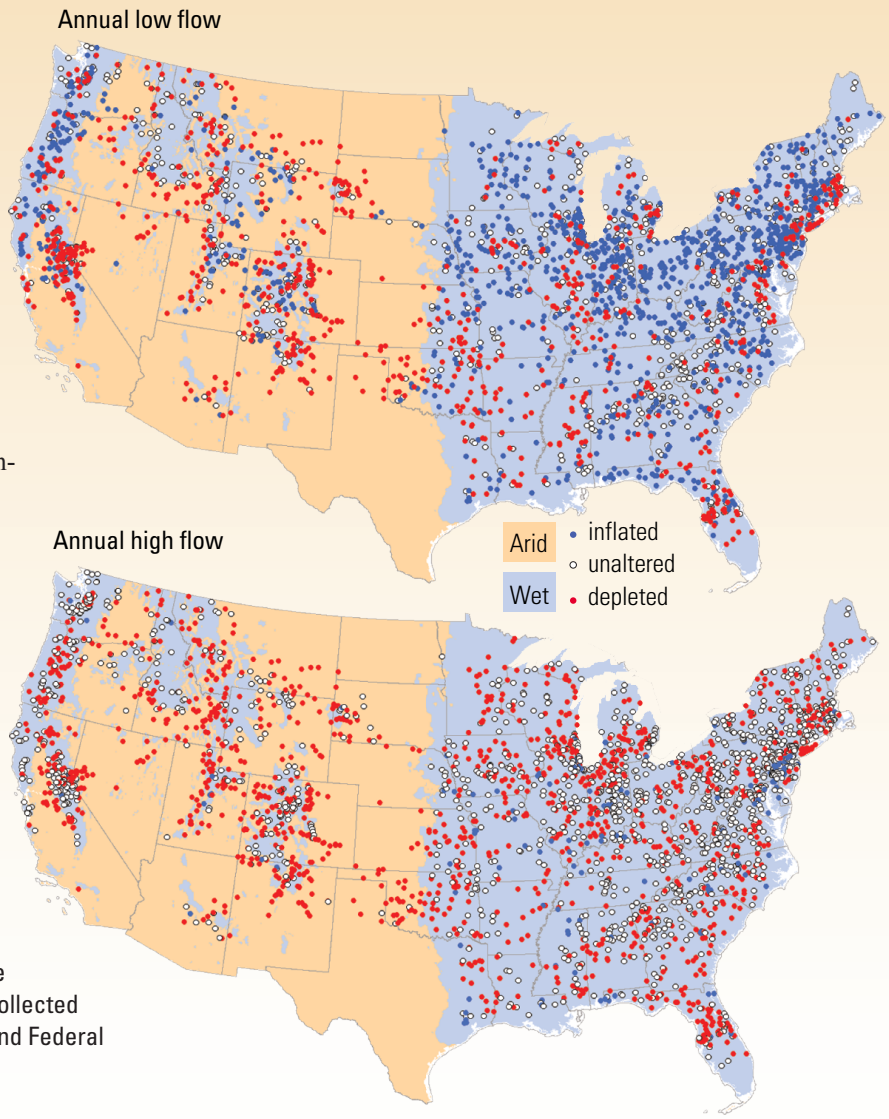


Figure 2. Annual high or low streamflows were modified in 86 percent of assessed stream sites. Streamflow modification was either depleted (less than) or inflated (greater than) relative to expected natural magnitudes. Although high flows were depleted throughout the United States, low flows tended to be depleted in arid regions and inflated in wet regions. These results highlight the value of long-term streamflow data collected by the USGS in cooperation with numerous local, State, and Federal partners across the Nation.

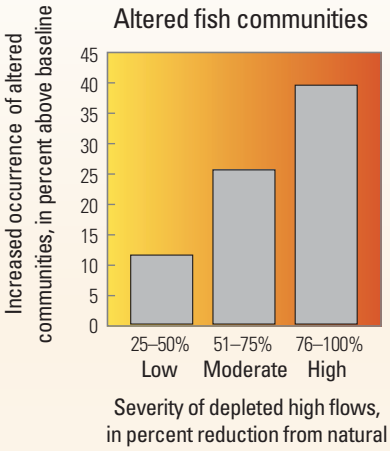


Figure 3. The occurrence of altered fish communities increased in streams with increasingly depleted high flows. Reservoirs, diversions, and other manmade changes to streams and their watersheds modify natural streamflows that are critical to the life stages of aquatic animals.

Baseline for graph was established from streams with minimal or no streamflow modification. Results were similar for modification of low flows.

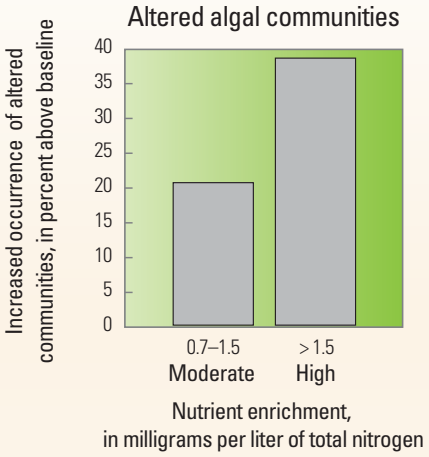


Figure 4. The occurrence of altered biological communities increased in streams with greater nutrient enrichment—a pattern that was most pronounced for algal communities.

Baseline for graph was established from streams with comparatively low (<0.7 milligram per liter) total nitrogen. Results were similar for total phosphorus.

Excess Nutrients

Excess concentrations of nutrients (also known as "nutrient enrichment") are widespread in the Nation's streams (Dubrovsky and others, 2010; U.S. Environmental Protection Agency, 2013). A variety of sources can contribute nutrients to streams, such as wastewater and industrial discharges, fertilizer and manure applications to agricultural land, runoff from urban areas, and atmospheric sources. Nutrient sources and resulting concentrations in streams vary across the Nation on the basis of regional differences in agricultural practices, urban land use, and natural factors such as climate and geology (Dubrovsky and others, 2010).

With increasing nutrient enrichment in stream water, the occurrence of altered algal communities increased from 21 to 39 percent (fig. 4). Biological alteration associated with elevated nutrient levels was most pronounced for algal communities, likely because of the direct link between nutrient availability and algal growth and reproduction. Alteration of algal communities is typified by changes in the types of algae—such as diatoms—that are predominant in a stream. Some types of diatoms thrive in streams with elevated nutrients and are referred to as "eutrophic diatoms." These species were a predominant part of algal communities in streams with elevated nutrients throughout the Nation (fig. 5). Deleterious effects to aquatic animals occur when excess nutrients cause excessive growths of algae and other aquatic plants, which consume oxygen in the water as they grow, die, and decompose. These effects, however, can vary from one stream to another as a result of differences in streamflow, amount of riparian shading, and water clarity (Dubrovsky and others, 2010).

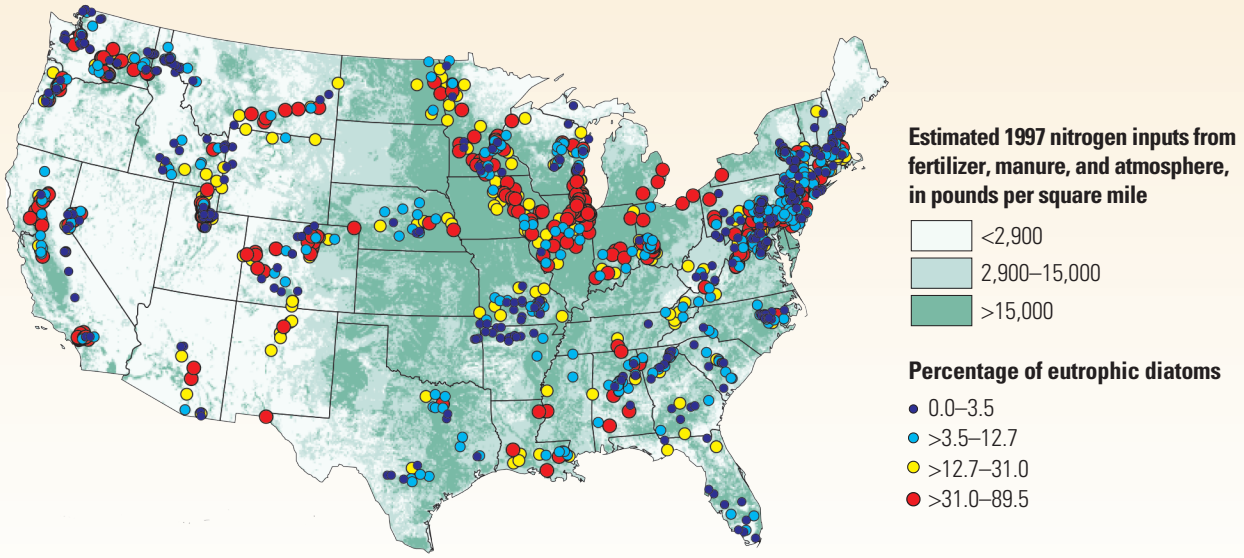
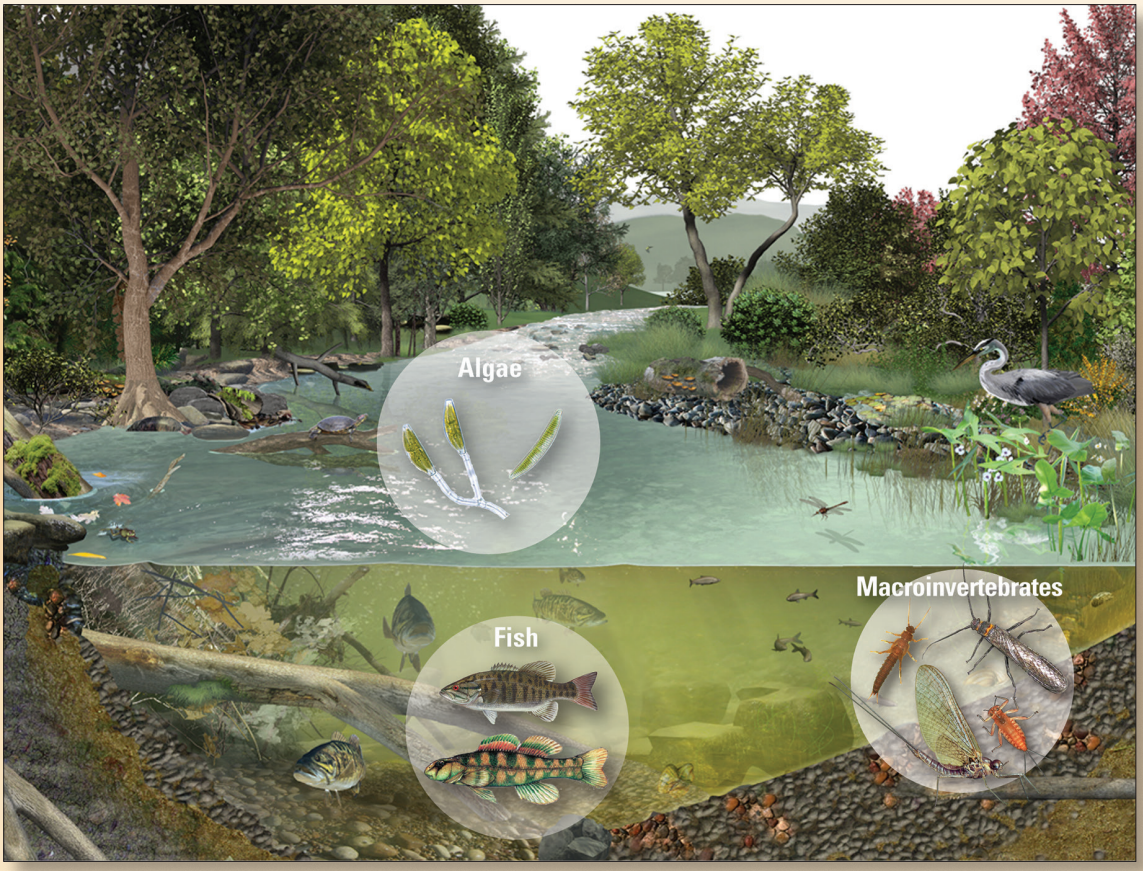


Figure 5. Eutrophic diatoms—a type of algae that prefer elevated nutrients—are a predominant part of algal communities across the Nation, particularly in regions with relatively high amounts of nutrient application such as the Corn Belt and irrigated agricultural lands in the West (from Dubrovsky and others, 2010).



Drawing by Frank Ippolito, *http://www.productionpost.com*

Biological communities inhabiting streams include algae, macroinvertebrates, and fish. Integrated assessments of multiple communities provide the most comprehensive measure of stream health because each community has important roles in the ecosystem and unique vulnerabilities to manmade changes in their physical and chemical surroundings.

Pesticides

Pesticides are detected in stream water in all land-use settings and typically reflect patterns of use in the watershed (Gilliom and others, 2006). Although pesticide concentrations are highly variable seasonally and from year to year, they may reach levels that are potentially harmful to biological communities, particularly in agricultural and urban streams (Gilliom and others, 2006).

The occurrence of altered macroinvertebrate communities increased from 20 to 42 percent in streams with greater potential toxicity of pesticide mixtures (fig. 6). This association is expected because stream macroinvertebrate communities are mainly composed of insects, and the most frequently detected—and potentially toxic—pesticides were insecticides (chlorpyrifos, carbaryl, and diazinon), which are designed to kill insects. After controlling for nutrients, salinity, habitat, and land use, streams with insecticide levels that exceeded aquatic-life benchmarks had 12 percent fewer macroinvertebrate taxa than streams without insecticide exceedances (Yuan and others, 2009). These findings suggest that pesticides contribute to reduced stream health in agricultural and urban streams, and support a growing body of literature documenting the adverse effects of pesticides on aquatic biological communities.

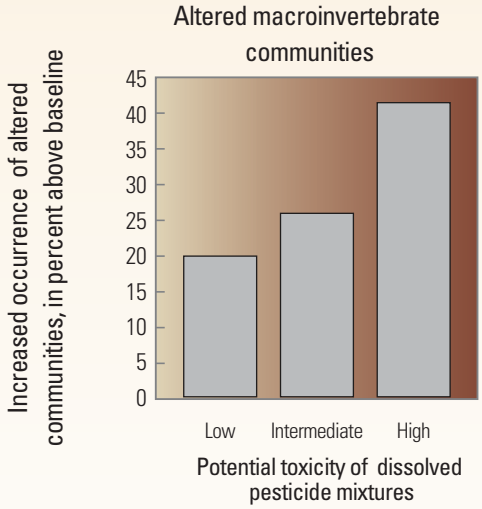


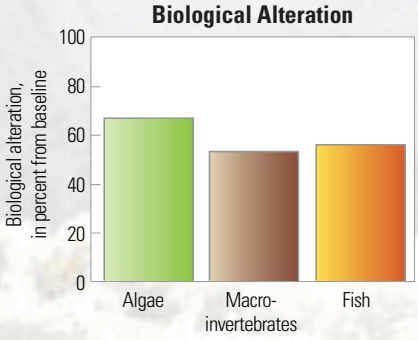
Figure 6. The occurrence of altered macroinvertebrate communities increased in streams where potential toxicity of dissolved pesticide mixtures was higher. Concentrations of widely used insecticides often occur in stream water at levels that are harmful to macroinvertebrate communities, which are dominated by aquatic insects. Baseline for graph was established from 132 streams where no pesticides were detected.

Unraveling the effects of multiple factors on stream health

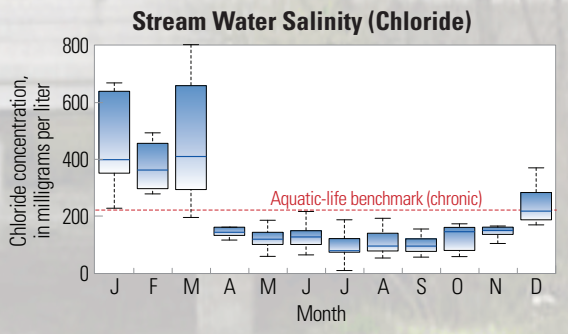
Scientists and managers often become environmental detectives when assessments indicate that stream health is diminished. They must determine which physical or chemical factors have been modified by human activities sufficiently to alter biological communities. This information is essential to developing appropriate management strategies. An example from Shingle Creek, an urban stream in Minnesota, is presented here.

Shingle Creek, Minnesota

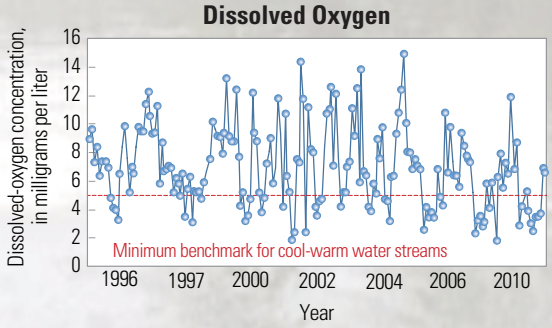
Algal, macroinvertebrate, and fish communities were severely altered in Shingle Creek, indicating poor stream health. Salinity—which frequently exceeds aquatic-life benchmarks during the winter—was originally thought to be the main cause. Followup investigations of other potential factors, however, showed that dissolved oxygen is often reduced and that streamflows fluctuated far beyond natural bounds, which is evidence that these factors also contribute to poor stream health. As a result of assessing multiple factors, managers now understand that improving the health of Shingle Creek requires remediation of several important physical and chemical factors.



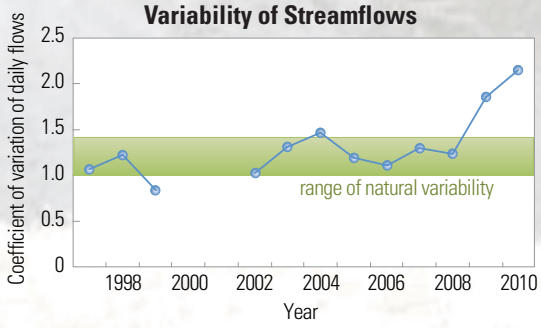
Algal, macroinvertebrate, and fish communities were altered more than 50 percent from baseline conditions.



Chloride concentrations often exceed the aquatic-life benchmark during the winter, when salt is applied to roadways in the watershed.



Dissolved-oxygen concentrations vary widely and often fall below State guidelines for the protection of aquatic life during summer when algae and other plant growth is highest.



Streamflow is often more variable than would naturally occur, indicating the potential for degradation of habitat for many aquatic species.

Management Implications

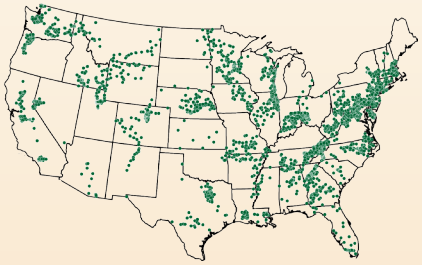
- **Assessments that are limited to a single biological community are likely to underestimate the effects of land and water use on stream health.**
- **Water quality is not independent of water quantity because flows are a fundamental part of stream health. Because flows are modified in so many streams and rivers, there are many opportunities to enhance stream health with targeted adjustments to flow management.**
- **Efforts to understand the causes of reduced stream health should consider the possible effects of nutrients and pesticides, in addition to modified flows, particularly in agricultural and urban settings.**
- **Stream health is often reduced due to multiple physical and chemical factors. Understanding how these multiple factors influence biological communities is essential in developing effective management strategies aimed at restoring stream health.**

Assessment Tools

Improving assessments of stream health

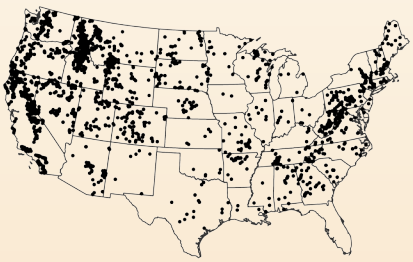
National Aquatic Bioassessment Database

The USGS BioData Retrieval System provides access to biological community and physical habitat data collected by USGS scientists from streams across the Nation. Data from more than 15,000 fish, aquatic macroinvertebrate, and algal community samples can be accessed at *https://aquatic.biodata.usgs.gov/*.



National Reference Site Database

The USGS and the Western Center for Monitoring & Assessment of Freshwater Ecosystems compiled biological data from reference-quality sites across the Nation. These data can be accessed at *http://www.cnr.usu.edu/wmc/htm/data*.



Diatoms of the United States

This online taxonomic guide and ecological resource provides identification information about diatoms of the United States. Expert contributors continue to add taxonomic information to the database, including high-quality images, morphological descriptions, and key features of each species. For many species, environmental response plots and geographic distribution maps are also included. This guide can be accessed at *http://westerndiatoms.colorado.edu*.

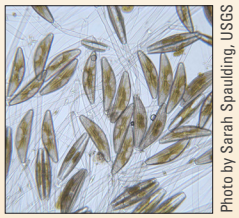


Photo by Sarah Spaulding, USGS

Diatoms, a group of mostly single-celled, microscopic algae, are abundant in nearly every habitat where water is found—oceans, lakes, streams, and soils.

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For Additional Information

Carlisle, D.M., Meador, M.R., Short, T.M., Tate, C.M., Gurtz, M.E., Bryant, W.L., Falcone, J.A., and Woodside, M.D., 2013, Ecological health in the Nation's streams, 1993–2005: U.S. Geological Survey Circular 1391.

Articles, posters, and a video describing the USGS assessment of the ecological health in the Nation's streams are available at *http://water.usgs.gov/nawqa/ecology/pubs/cir-1391/*.