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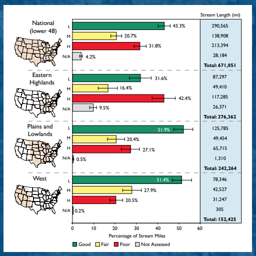
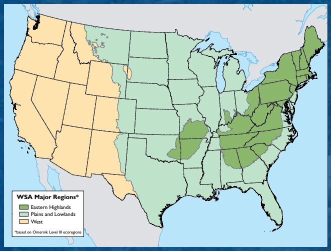
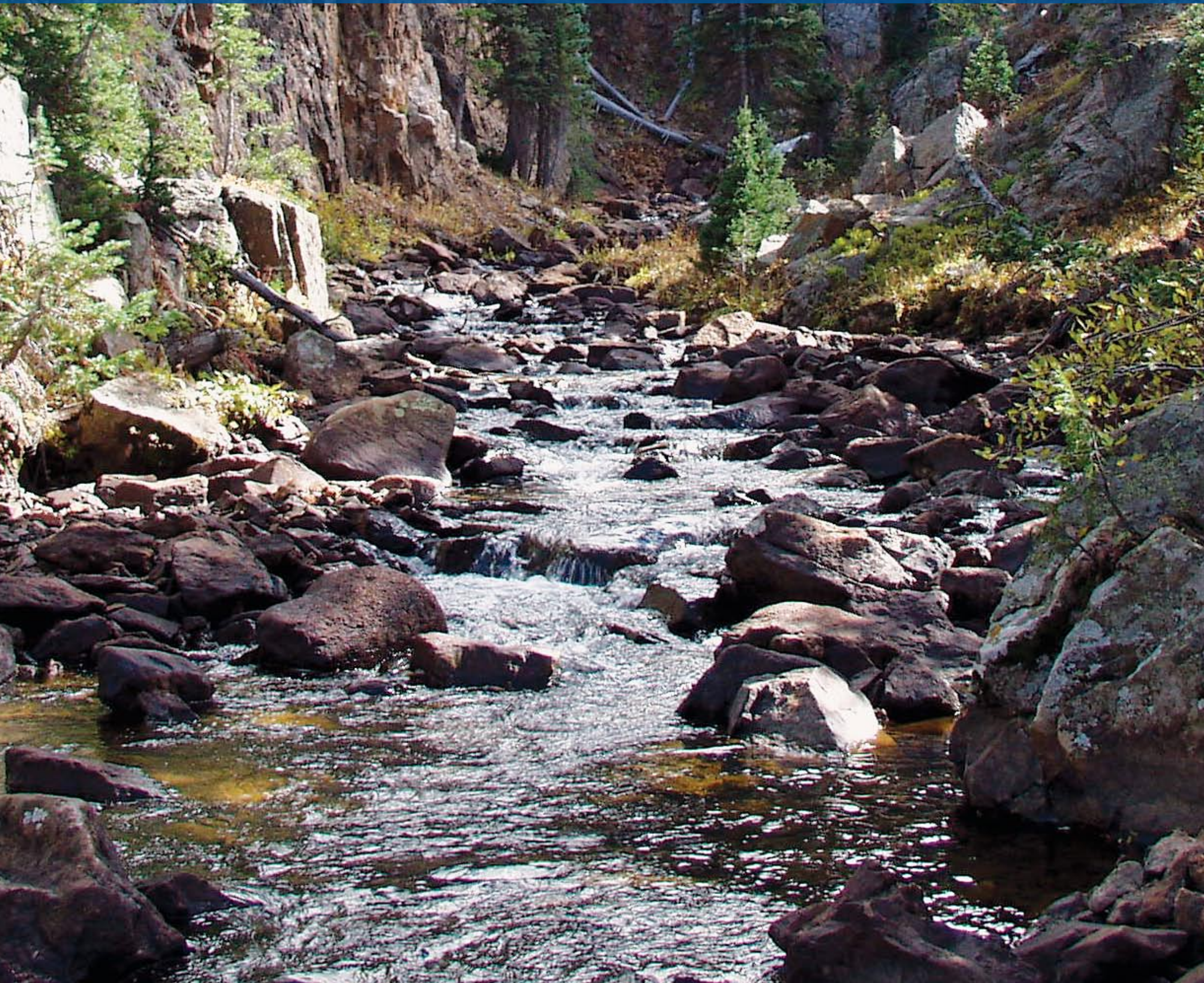
Wadeable Streams Assessment

A Collaborative Survey of the Nation's Streams







Front cover photo courtesy of the Colorado Division of Wildlife

Inside cover photo courtesy of Michael L. Smith, U.S. Fish and Wildlife Service

Acknowledgments

This report resulted from a ground-breaking collaboration on stream monitoring. States came together with the U.S. Environmental Protection Agency (EPA) to demonstrate a cost-effective approach for answering one of the nation's most basic water quality questions: What is the condition of our nation's streams?

The EPA Office of Water would like to thank the many participants who contributed to this important effort and the scientists within the EPA Office of Research and Development for their research and refinement of the survey design, field protocols, and indicator development. Through the collaborative efforts of state environmental and natural resource agencies, federal agencies, universities, and other organizations, more than 150 field biologists were trained to collect environmental samples using a standardized method, and more than 25 taxonomists identified as many as 500 organisms in each sample. Each participating organization attended a national meeting to discuss and formulate the data analysis approach, as well as regional meetings to evaluate and refine the results presented in this report.

Collaborators

Alaska Department of Environmental Conservation
Arizona Game and Fish Department
Arkansas Department of Environmental Quality
California Department of Fish and Game
California State Water Resources Control Board
Colorado Department of Public Health and Environment
Colorado Division of Wildlife
Connecticut Department of Environmental Protection
Delaware Department of Natural Resources and Environmental Control
Georgia Department of Natural Resources
Idaho Department of Environmental Quality
Illinois Environmental Protection Agency
Iowa Department of Natural Resources
Kansas Department of Health and Environment
Kentucky Division of Water
Louisiana Department of Environmental Quality
Maine Department of Environmental Protection
Maryland Department of Natural Resources
Michigan Department of Environmental Quality
Minnesota Pollution Control Agency
Mississippi Department of Environmental Quality
Missouri Department of Conservation
Montana Department of Environmental Quality
Nevada Division of Environmental Protection
New Hampshire Department of Environmental Services
New Jersey Department of Environmental Protection
New Mexico Environment Department
New York State Department of Environmental Conservation
North Carolina Division of Water Quality
North Dakota Department of Health
Ohio Environmental Protection Agency
Oklahoma Conservation Commission
Oklahoma Water Resources Board
Oregon Department of Environmental Quality
Pennsylvania Department of Environmental Protection
South Carolina Department of Health and Environmental Control
South Dakota Department of Environment and Natural Resources
South Dakota Game, Fish and Parks
Tennessee Department of Environment and Conservation
Texas Commission of Environmental Quality

Utah Division of Water Quality
Vermont Department of Environmental Conservation
Virginia Department of Environmental Quality
Washington State Department of Ecology
West Virginia Department of Environmental Protection
Wisconsin Department of Natural Resources
Wyoming Department of Environmental Quality
Fort Peck Assiniboine and Sioux Tribes
Guam Environmental Protection Agency
U.S. Geological Survey
U.S. EPA, Office of Environmental Information
U.S. EPA, Office of Water
U.S. EPA, Office of Research and Development
U.S. EPA, Regions 1–10
Center for Applied Bioassessment and Biocriteria
Central Plains Center for Bioassessment
New England Interstate Water Pollution Control Commission
The Council of State Governments
Great Lakes Environmental Center
Tetra Tech, Inc.
EcoAnalysts
University of Arkansas
Mississippi State University
Oregon State University
Utah State University

The data analysis team painstakingly reviewed the data set to ensure its quality and performed the data analysis. This team included Phil Kaufmann, Phil Larsen, Tony Olsen, Steve Paulsen, Dave Peck, John Stoddard, John Van Sickle, and Lester Yuan from the EPA Office of Research and Development; Alan Herlihy from Oregon State University; Chuck Hawkins from Utah State University; Daren Carlisle from the U.S. Geological Survey; and Michael Barbour, Jeroen Gerritson, Erik Lepow, Kristen Pavlik, and Sam Stribling from Tetra Tech, Inc.

The report was written by Steve Paulsen and John Stoddard from the EPA Office of Research and Development and Susan Holdsworth, Alice Mayio, and Ellen Tarquinio from the EPA Office of Water. Major contributions to the report were made by John Van Sickle, Dave Peck, Phil Kaufmann, and Tony Olsen from the EPA Office of Research and Development and Peter Grevatt and Evan Hornig from EPA Office of Water, Alan Herlihy from Oregon State University, Chuck Hawkins from Utah State University, and Bill Arnold from the Great Lakes Environmental Center. Technical editing and document production support was provided by RTI International. This report was significantly improved by the external peer review conducted by Dr. Stanley V. Gregory, Ecologist, Oregon State University; Dr. Kenneth Reckhow, Environmental Engineer, Duke University; Dr. Kent Thornton, Principal Ecologist, FTN Associates; Dr. Scott Urquhart, Statistician, Colorado State University; and Terry M. Short of the U.S. Geological Survey. The Quality Assurance Officer for this project was Otto Gutenson from the EPA Office of Water.

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Figures

Acronym List

˚F	degrees Fahrenheit
ANC	acid neutralizing capacity
BMPs	best management practices
CAAA	Clean Air Act Amendments
CWA	Clean Water Act
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
FWS	U.S. Fish and Wildlife Service
km	kilometers
mi^2	square miles
NAPAP	National Acid Precipitation Program
NCA	National Coastal Assessment
NCCR	National Coastal Condition Report
NCCR II	National Coastal Condition Report II
NEP	National Estuary Program
NEP CCR	National Estuary Program Coastal Condition Report
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NOAA	National Atmospheric and Oceanic Administration
O/E	observed/expected
PCBs	polychlorinated biphenyls
RBS	relative bed stability
TDS	total dissolved solids
µeq/L	microequivalents per liter
USGS	U.S. Geological Survey
VOCs	volatile organic compounds
WSA	Wadeable Streams Assessment

Executive Summary

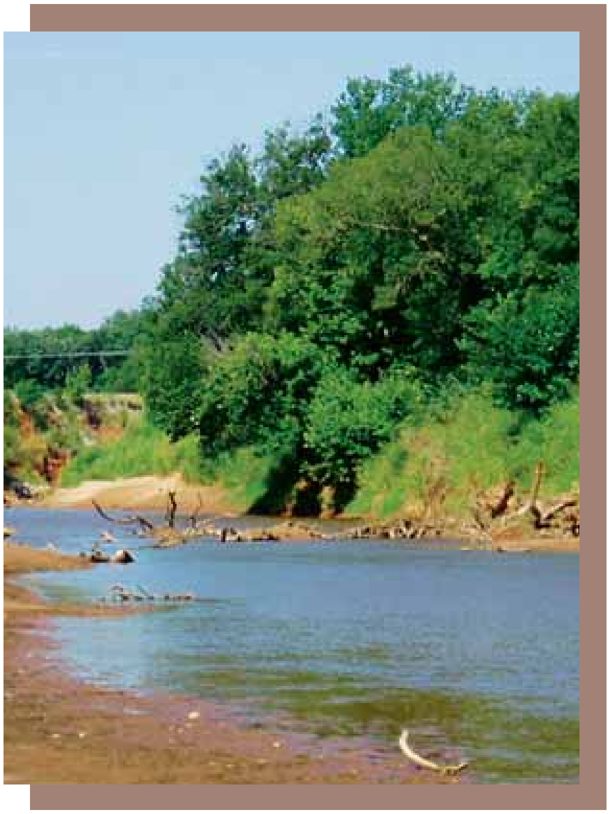
Photo courtesy of Monty Porter

Executive Summary

"I started out thinking of America as highways and state lines. As I got to know it better, I began to think of it as rivers. America is a great story, and there is a river on every page of it."

This quote by well-known journalist Charles Kuralt reflects on the central role that rivers and streams have played in shaping the history and character of our nation. Because the health and survival of U.S. families and communities are dependent on these waterbodies, their condition, as well as how they are protected, reflects our values and choices as a society.

The Wadeable Streams Assessment (WSA) provides the first statistically defensible summary of the condition of the nation's streams and small rivers. In the 35 years since the passage of the Clean Water Act (CWA), the U.S. Congress, American public, and other interested parties have asked the U.S. Environmental Protection Agency (EPA) to describe the water quality condition of U.S. waterbodies. These requests have included seemingly simple questions: Is there a water quality problem? How extensive is the problem? Does the problem occur in "hotspots" or is it widespread? Which environmental stressors affect the quality of the nation's streams and rivers, and which are most likely to be detrimental? This WSA report presents the initial results of what will be a long-term partnership between EPA, other federal agencies, states, and tribes to answer these questions.



Little Washita River, OK, in the Southern Plains ecoregion (Photo courtesy of Monty Porter).

The WSA encompasses the wadeable streams and rivers that account for a vast majority of the length of flowing waters in the United States. To perform the assessment, EPA, states, and tribes collected chemical, physical, and biological data at 1,392 wadeable, perennial stream locations to determine the biological condition of these waters and the primary stressors affecting their quality. Research teams collected samples at sites chosen using a statistical design to ensure representative results. The results of this analysis provide a clear assessment of the biological quality of wadeable, perennial streams and rivers across the country, as well as within each of three major climatic and landform regions and nine ecological regions, or ecoregions.

The information provided in this report fills an important gap in meeting the requirements of the CWA. The purpose of the WSA is four-fold:

- Report on the ecological (biological, chemical, and physical) condition of all wadeable, perennial streams and rivers within the conterminous United States. (Pilot assessment projects are also underway in Alaska and Hawaii.)
- Describe the biological condition of these systems using direct measures of aquatic life. Assessments of stream quality have historically relied primarily on chemical analyses of water, or sometimes, on the status of game fish.
- Identify and rank the relative importance of chemical and physical stressors (disturbances) affecting stream and river condition.
- Enhance the capacity of states and tribes to include these design and measurement tools in their water quality monitoring programs so that assessments will be ecologically and statistically comparable, both regionally and nationally.

The results of the WSA show that 42% of the nation's stream length is in poor biological condition compared to least-disturbed reference sites in the nine ecoregions, 25% is in fair biological condition, and 28% is in good biological condition (Figure ES-1). Five percent of the nation's stream length was not assessed for biological condition during the WSA.

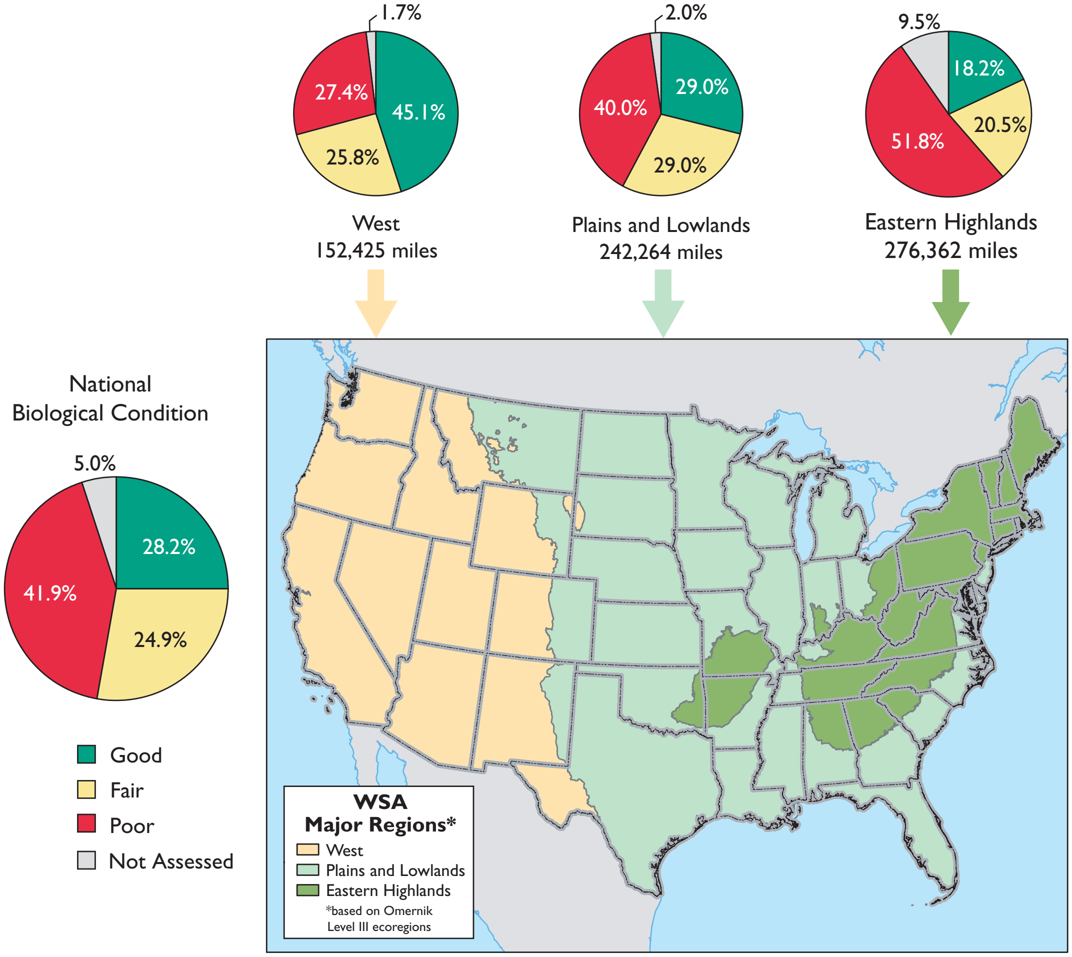


Figure ES-1. Biological condition of wadeable streams (U.S. EPA/WSA).

Of the three major regions discussed in this report, the West is in the best biological condition, with 45% of stream length in good biological condition. The Plains and Lowlands region has almost 30% of stream length in good biological condition and 40% in poor biological condition. The Eastern Highlands region presents the most concerns, with only 18% of stream length in good biological condition and 52% in poor biological condition.

The WSA also examines the key factors most likely responsible for diminishing biological quality in flowing waters, as determined by aquatic macroinvertebrate communities. The most widespread stressors observed across the country and in each of the three major regions are nitrogen, phosphorus, riparian disturbance, and streambed sediments. Increases in nutrients (e.g., nitrogen and phosphorus) and streambed sediments have the highest impact on biological condition; the risk of having poor biological condition was two times greater for streams scoring poor for nutrients or streambed sediments than for streams that scored in the good range for the same stressors (Figure ES-2).

Understanding the current condition of the nation's wadeable streams and rivers is critical to supporting the development of water quality management plans and priorities that help maintain and restore the ecological condition of these resources. This report provides a primary-baseline assessment to track water quality status and trends. The results of the WSA and similar assessments in the future will inform the public, water quality managers, and elected officials of the effectiveness of efforts to protect and restore water quality, as well as the potential need to refocus these efforts.

Readers who wish to learn more about the technical background of the WSA are directed to literature cited in the References section at the end of this report and to material posted on the EPA Web site at http://www.epa.gov/owow/streamsurvey.

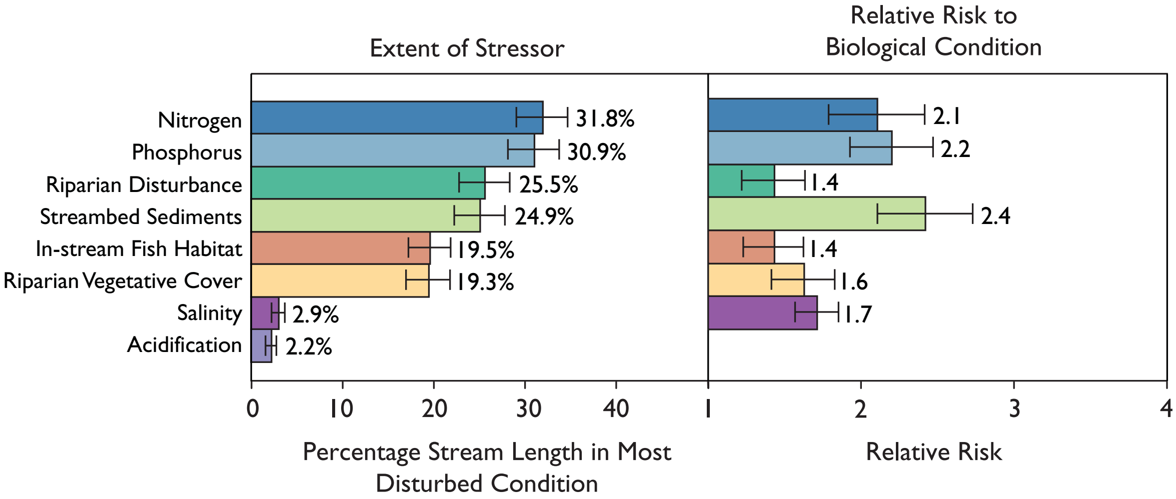


Figure ES-2. Extent of stressors and their relative risk to the biological condition of the nation's streams (U.S. EPA/WSA).

Introduction

Photo courtesy of the Georgia Department of Natural Resources

Introduction

In 1972, the U.S. Congress enacted the landmark Clean Water Act (CWA) to protect the nation's vital water resources. A critical section of the CWA calls for periodic accounting to Congress and the American public on the success or failure of efforts to protect and restore the nation's waterbodies. In recent years, a number of groups reviewed the available data and concluded that the U.S. Environmental Protection Agency (EPA) and state environmental agencies have been unable to provide Congress and the public with adequate information regarding the condition of the nation's waterbodies.

In 2000, the General Accounting Office issued a report noting that EPA and the states could not make statistically valid inferences about water quality and lacked data to support management decisions. A National Research Council report in 2001 found that a uniform, consistent approach to ambient monitoring and data collection was necessary to support core water programs. In 2002, the National Academy of Public Administration and the H. John Heinz III Center for Science, Economics, and the Environment issued similar conclusions.

Following the 2002 release of the Heinz Center's report *The State of the Nation's Ecosystems*, the national newspaper USA Today published an editorial discussing the lack of environmental information available to the public. This editorial emphasized the failure of state and federal agencies to fund the collection of necessary environmental data despite very effective collection of comparable information on the U.S. economy, population, energy usage, human health issues, and crime rate. The editorial concluded that "without such information, the public doesn't know when to celebrate environmental successes, tackle new threats, or end efforts that throw money down a drain" (USA Today, September 21, 2002).

Little Washita River, OK, in the Southern Plains ecoregion (Photo courtesy of Monty Porter).

To bridge this information gap, EPA, other federal agencies, states, and tribes, are collaborating to provide the public with improved environmental information. This collaboration includes a new monitoring effort to assess the quality of the nation's waterbodies, an effort that has produced reports on three national water quality assessments during the past five years for coastal and estuarine waters (see *Highlight: National Report on Coastal Waters*). Similar efforts are planned for other water resource assessments in the future. The Wadeable Streams Assessment (WSA)—the first nationally consistent, statistically valid study of the nation's wadeable streams—marks the continuation of a commitment to produce statistically valid scientific assessments of the nation's fresh waters.

State water quality agencies, tribes, and other partners, with support from EPA, conducted the work for the WSA using standardized methods at all sites to ensure the comparability of results across the country. Beyond yielding scientifically credible information on the condition and health of the nation's wadeable streams, the WSA was designed to provide states with funding and expertise that enhances their ability to monitor and assess the quality of their waters.

EPA and its collaborating partners plan to conduct similar assessments of other types of waterbodies (e.g., lakes, rivers, and wetlands) in the future, with the goal of producing updated assessments for each type of waterbody every five years. These repeated studies will ensure that the public remains informed as to whether the collective efforts to protect and restore the nation's waters are meeting with success.

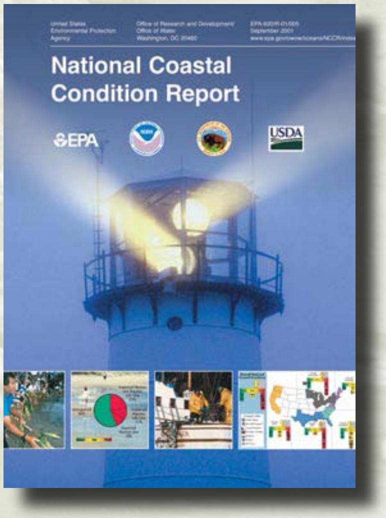
Photo courtesy of Gary Kramer, U.S. Department of Agriculture Natural Resources Conservation Service.

Highlight

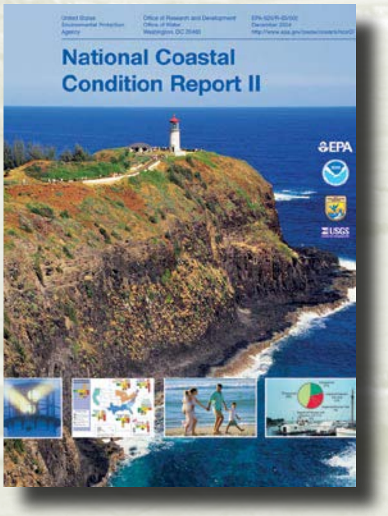
National Reports on Coastal Waters

The National Coastal Assessment (NCA) surveys the condition of the nation's coastal resources, as well as state efforts to protect, manage, and restore coastal ecosystems. The results of these surveys are compiled periodically into the *National Coastal Condition Report* (NCCR) series. The states, EPA, and partner agencies, including the National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and U.S. Fish and Wildlife Service (FWS), issued the *National Coastal Condition Report II* (NCCR II) in January 2005 as the second in this series of reports on environmental surveys of U.S. coastal waters. The NCCR II includes evaluations of 100% of the nation's estuaries in the conterminous 48 states and Puerto Rico. Federal, state, and local agencies collected more than 50,000 samples between 1997 and 2000 for the NCCR II, using nationally consistent methods and a probability-based design to assess five key indices of coastal water health: water quality, coastal habitat loss, sediment quality, benthic community condition, and fish tissue contaminants levels.

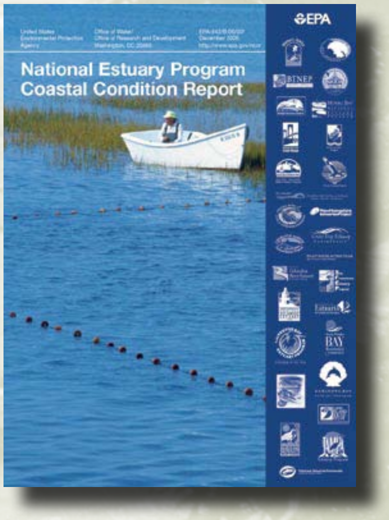
The *National Estuary Program Coastal Condition Report* (NEP CCR) focuses specifically on the condition of the 28 estuaries in the National Estuary Program (NEP) using data collected from 1997 through 2003 for EPA's NCA. The NEP CCR also presents monitoring data collected and analyzed by each individual NEP and its partners for a variety of estuarine quality indicators. The 28 NEPs are using these data to develop and implement sets of program-specific indicators of estuarine condition.



National Coastal Condition Report



National Coastal Condition Report II



National Estuary Program Coastal Condition Report

Chapter 1

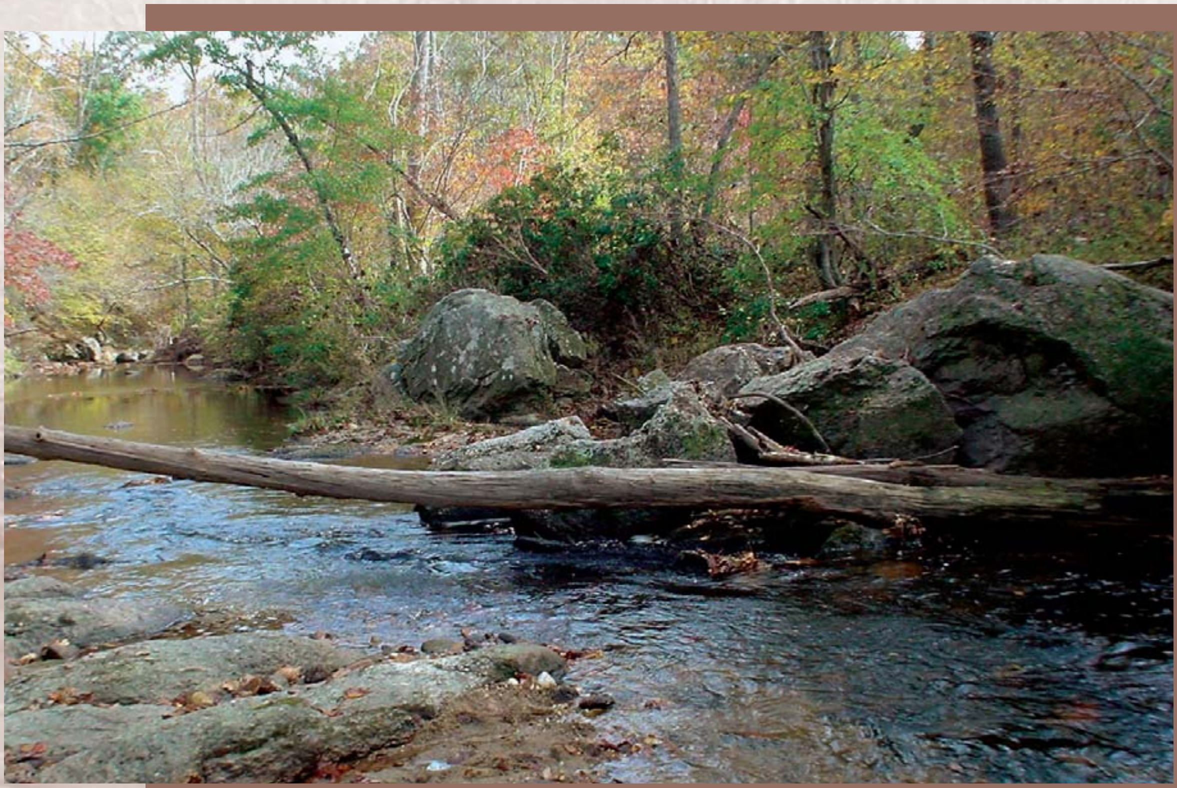


Photo courtesy of the Georgia Department of Natural Resources

Design of the Wadeable Streams Assessment

Design of the Wadeable Streams Assessment

Why Focus on Wadeable Streams?

Like the network of blood vessels that supply life-giving oxygen and nutrients to all parts of the human body, streams and rivers form a network that carries essential water to all parts of the nation. The human body has far more small capillaries than large, major arteries and veins; similarly, only a few U.S. rivers span large portions of the country (e.g., the Mississippi, Missouri, or Columbia rivers). Most of the nation's waterways are much smaller stream and river systems that form an intimate linkage between land and water.

The WSA addresses these smaller systems, which ecologists often refer to as "wadeable" because they are small and shallow enough to adequately sample without a boat. Almost every state, university, federal agency, and volunteer group involved in water quality monitoring has experience sampling these smaller flowing waters; therefore, a wide range of expertise was available for the WSA's nationwide monitoring effort.

About 90% of perennial stream and river miles in the United States are small, wadeable streams. Stream and river ecologists commonly use the term Strahler stream order to refer to stream size, and wadeable streams generally fall into the 1st- through 5th-order range (Figure 1). First-order streams are the headwaters of a river, where the life of a river begins; as streams join one another, their stream order increases. It is important to note that many 1st-order streams, particularly those located in the western United States, do not flow continuously. These intermittent or ephemeral streams were not included in the WSA because well-developed indicators to assess these waterbodies do not yet exist. At the other end of the range are larger-order rivers and streams that

Sawmill Creek, MA, in the Northern Appalachians ecoregion
(Photo courtesy of Colin Hill, Tetra Tech, Inc.).

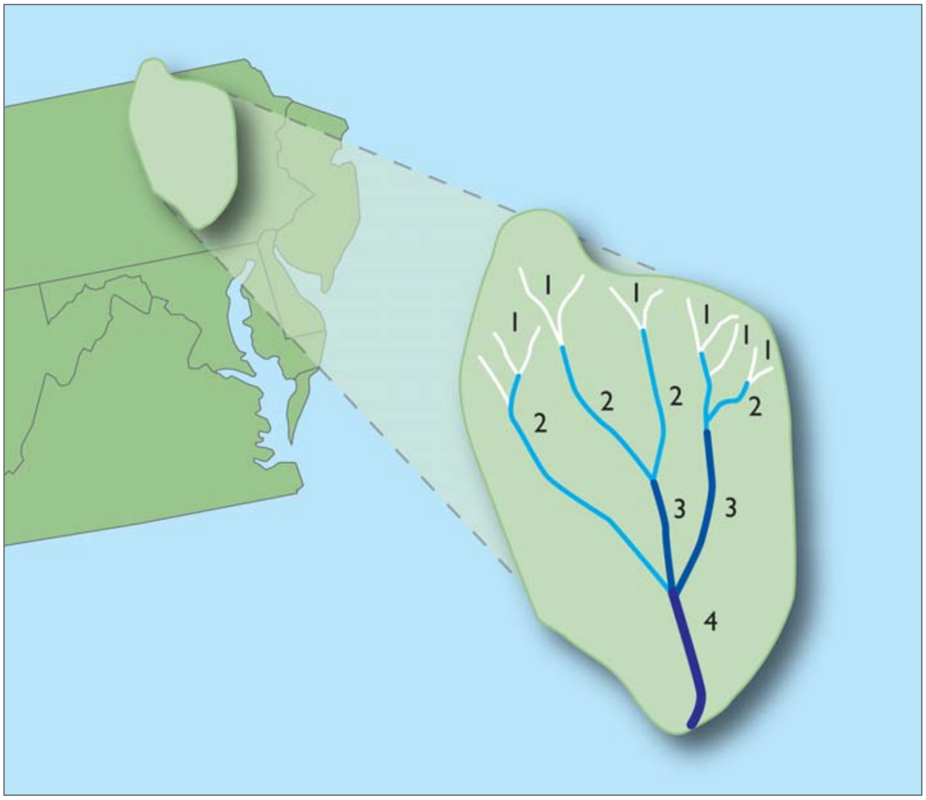


Figure 1. Strahler stream order diagram (U.S. EPA/WSA). Stream size is categorized by Strahler stream order, demonstrated here for a watershed. The confluence (joining) of two 1st-order streams forms a 2nd-order stream; the confluence of two 2nd-order streams forms a 3rd-order stream.

are too deep for wadeable sampling methods. These deeper waterbodies will be included in a future survey of non-wadeable rivers.

Stream order (stream size) affects a stream's natural characteristics, including the biological communities that live in the stream, such as fish and invertebrates. Very small 1st-order and 2nd-order streams are often quite clear and narrow and are frequently shaded by grasses, shrubs, and trees that grow along the stream bank (Figure 2). The food base of these streams is found along the stream bank and tends to consist of leaves and terrestrial insects, which dominate the streams' ecology, along with algae that attach to rocks and wood, aquatic insects adapted to shredding leaves and scraping algae, and small fish that feed on these organisms. In contrast, larger 6th- and 7th-order rivers typically appear muddy because their flow carries accumulated sediments downstream. These rivers are wide enough that the canopy cover along their banks shades only a narrow margin of water along the river's edge. The food base for these waterbodies shifts towards in-stream sources, such as algae; downstream drift of small organisms; and deposition of fine detritus. Although the aquatic communities of larger rivers include the algae and terrestrial insects found in streams, these rivers are dominated by insects adapted to filtering and gathering fine organic particles, and larger fish that are omnivorous (feeding on plants and animals) and/or piscivorous (feeding on smaller fish).

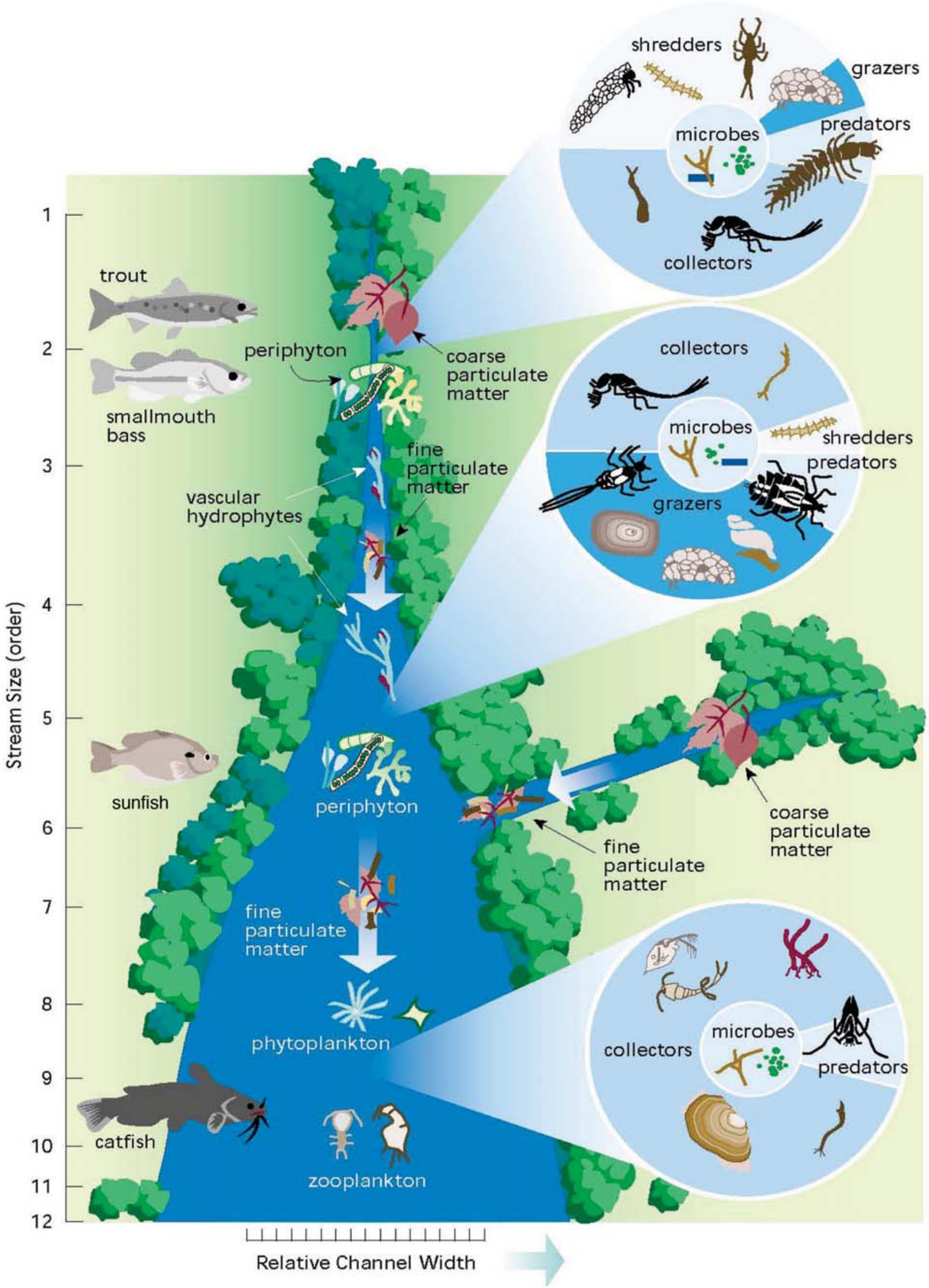


Figure 2. Stream characteristics change as the stream's size or stream order increases (Vannote et al., 1980).

What Area Does the WSA Cover?

This WSA encompasses the wadeable streams of the conterminous United States, or lower 48 states (Figure 3). This land area covers 3,007,436 square miles (mi^2) and includes private, state, tribal, and federal land. Although not included in this report, initial stream-sampling projects outside the conterminous United States have begun and will be included in future assessments. For example, scientists in Alaska sampled streams in the Tanana River Basin (a subbasin to the Yukon River) during 2004 and 2005, and they expect to report their results in 2007; Guam has begun implementation of a stream survey; and Puerto Rico is developing indicators for assessing the condition of its tropical streams. In addition, the State of Hawaii began stream sampling using WSA techniques on the island of Oahu in 2006.

State boundaries offer few insights into the true nature of features that mold our streams and rivers. The most fundamental trait that defines U.S. waters is annual precipitation (Figure 4). A sharp change occurs on either side of the

Figure 3. Major rivers and streams of the conterminous United States (NationalAtlas.gov, 2006). Major rivers comprise only 10% of the length of U.S. flowing waters, whereas the nation's wadeable streams and rivers comprise 90% of the length of U.S. flowing waters.

100th longitude that runs from west Texas through North Dakota, with precipitation falling plentifully to the east, but sparsely to the west. (The high mountains of the western United States and the Pacific coast are exceptions to the general scarcity of water in the West.) The east-west divide in moisture has not only shaped the character of the nation's waters, but also how they are used, valued, and the even the legal systems with which they are managed. A second divide that defines the nature of U.S. rivers and streams is the north-south gradient in temperature.

Young Womans Creek, PA, in the Southern Appalachians ecoregion (Photo courtesy of the Great Lakes Environmental Center).

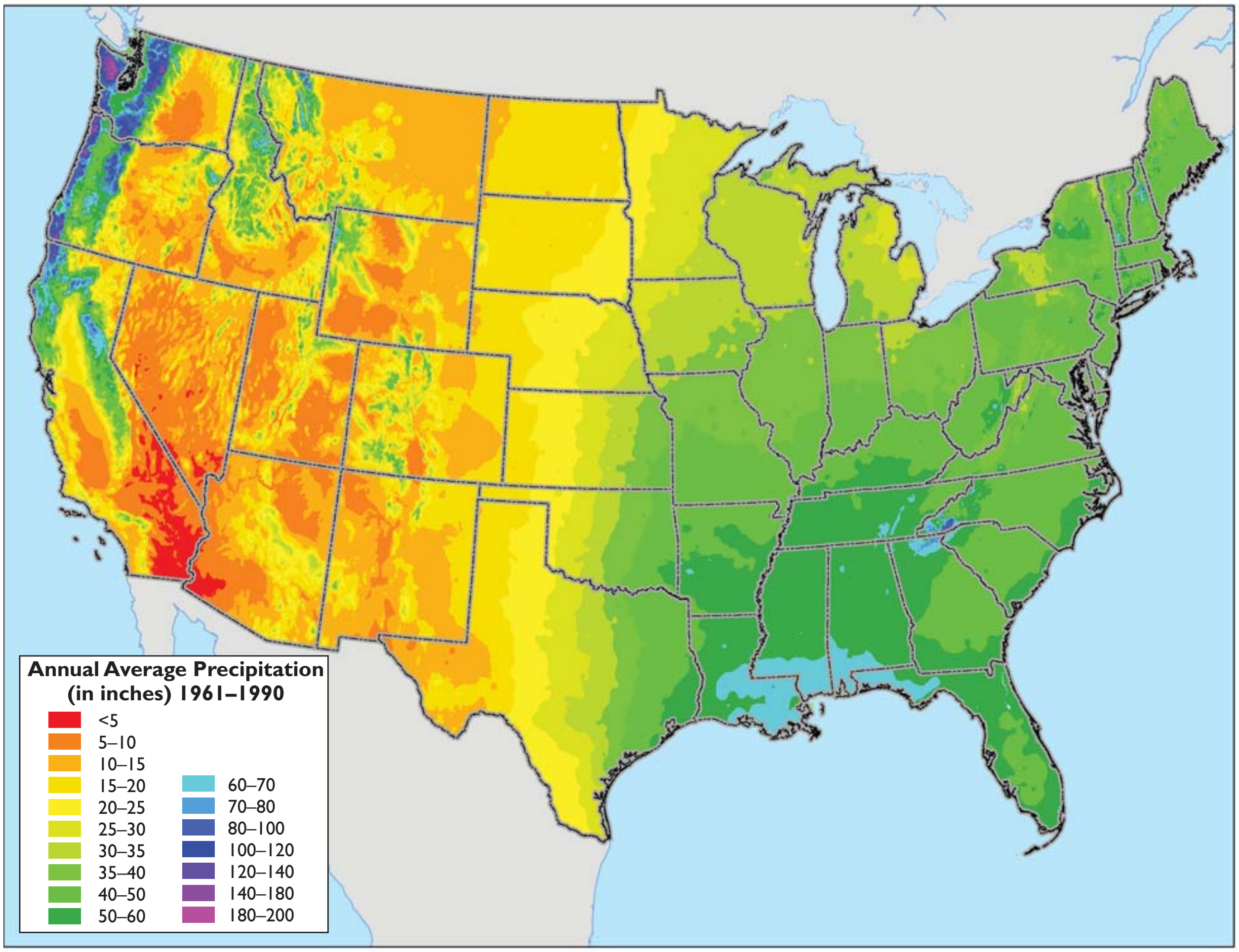


Figure 4. Average annual precipitation of the United States, 1961–1990 (NOAA, National Climatic Data Center). The 100th longitude meridian runs from Texas north through North Dakota and reveals a major gradient of precipitation that defines differences in western and eastern streams.

The nation includes a wide diversity of landscapes, from the varied forests of the East, to the immense agricultural plains and grasslands of the Midwest, to the deserts and shrublands of the Southwest, to the giant mountain ranges of the West (Figure 5). In the eastern part of the country, the Appalachian mountains run from Maine to Alabama, crossing climatic boundaries and separating the waters flowing to the Atlantic Ocean from those flowing to the Gulf of Mexico. The larger mountain ranges in the West link their landscapes together: the Rockies through the heart of the West; the Cascades, which crown the Northwest in snow; the Sierra Nevada in California; and the Coastal Range, which plummets to the Pacific Ocean, with a fault-block shoreline that stretches from the Santa Monica mountains to Kodiak Island. The Coastal Plains of the East and Southeast and the Great Plains of the interior provide other major landform features that mark the country.

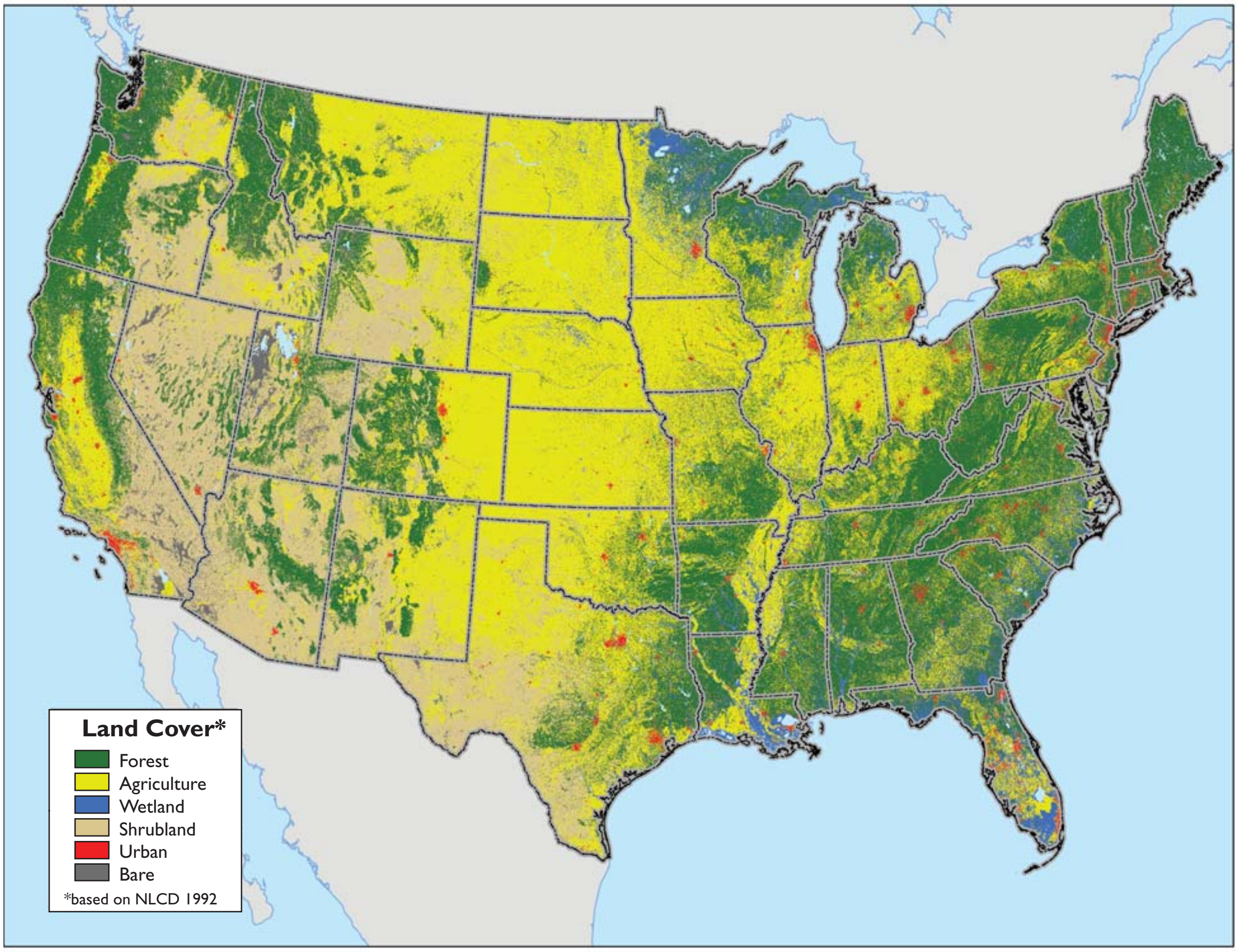


Figure 5. Major land cover patterns of the conterminous United States (USGS, 2000).

The establishment and spread of European colonies and the Industrial Revolution intensified the transformation of the nation's natural landscape, as greater numbers of people arrived and modified many of the features of the land and waters. As the nation's population grew and cities and towns were established, tens of thousands of dams were constructed to alter the flow of virtually every major river in the United States.

Historically, people have tended to live where water is more abundant. Current population patterns based on 2000 U.S. Census Bureau data reflect the historical abundance of waters in the East and forecast the growing challenges facing the water-scarce regions in the West, where population has grown in recent years (Figure 6). The current and future condition of the nation's waters will continue to be influenced by population patterns, as well as how the components of a watershed, including surface water, groundwater, and the land itself, are used.

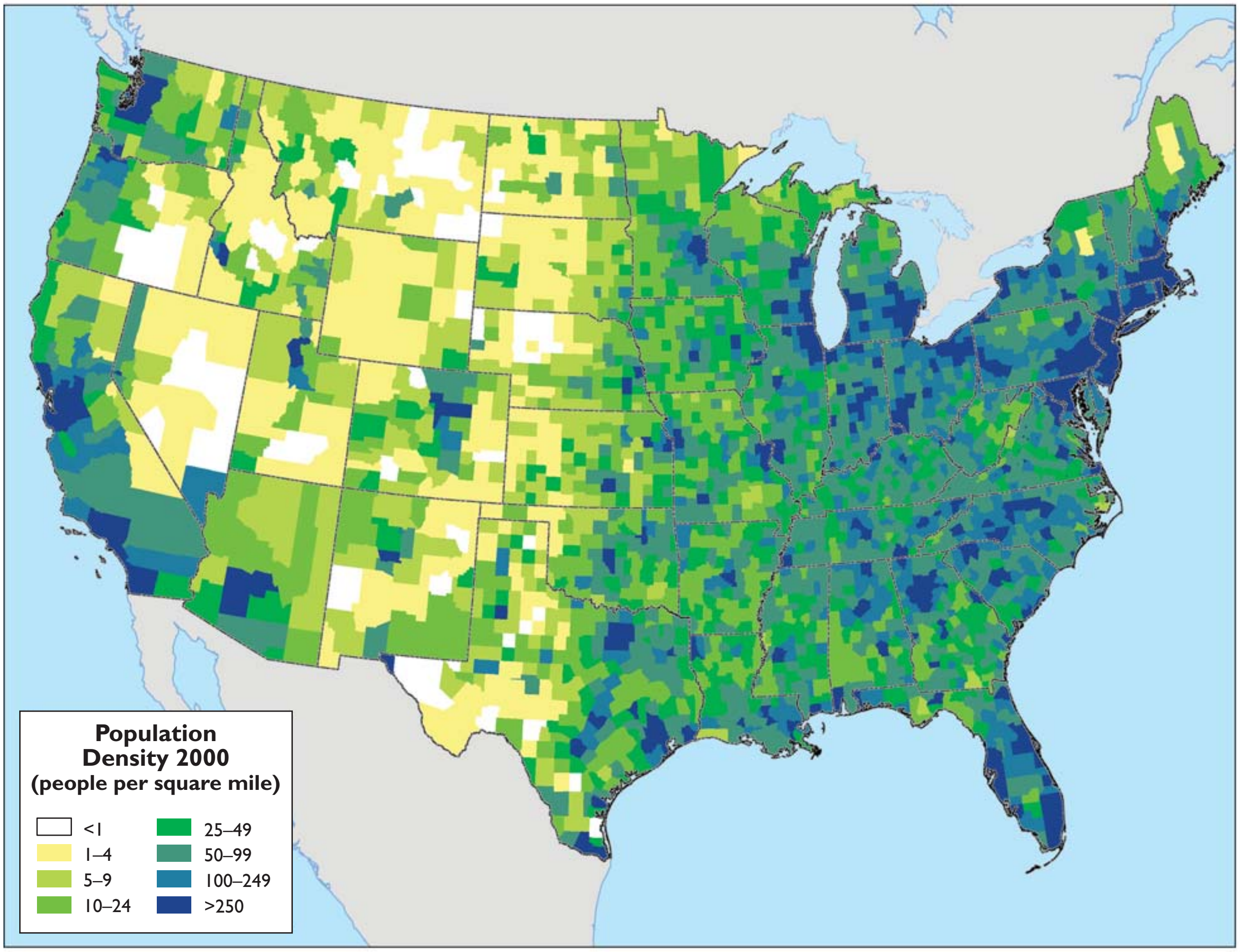


Figure 6. Human population density (people per square mile) based on 2000 U.S. Census Bureau data (ESRI, 2005).

What Areas Are Used to Report WSA Results?

The conterminous United States is the broadest-scale unit for which WSA results are reported. For this report, this area has been split into three major regions—the Eastern Highlands, the Plains and Lowlands, and the West. These three regions correspond to major climate and landform patterns across the United States (Figure 7).

The Eastern Highlands region is composed of the mountainous areas east of the Mississippi River and includes the piedmont to the east of the Appalachians and the interior plateau to their west. The Plains and Lowlands region encompasses the Atlantic and Gulf of Mexico coastal plains and the lowlands of the Mississippi Delta, as well as the portions of the Midwest from the Dakotas down through most of Texas. The West region includes the western portion of the country, from the desert southwestern United States and the Rocky Mountains to the Pacific Ocean. Chapter 2 of this report describes the WSA results for these three major regions.

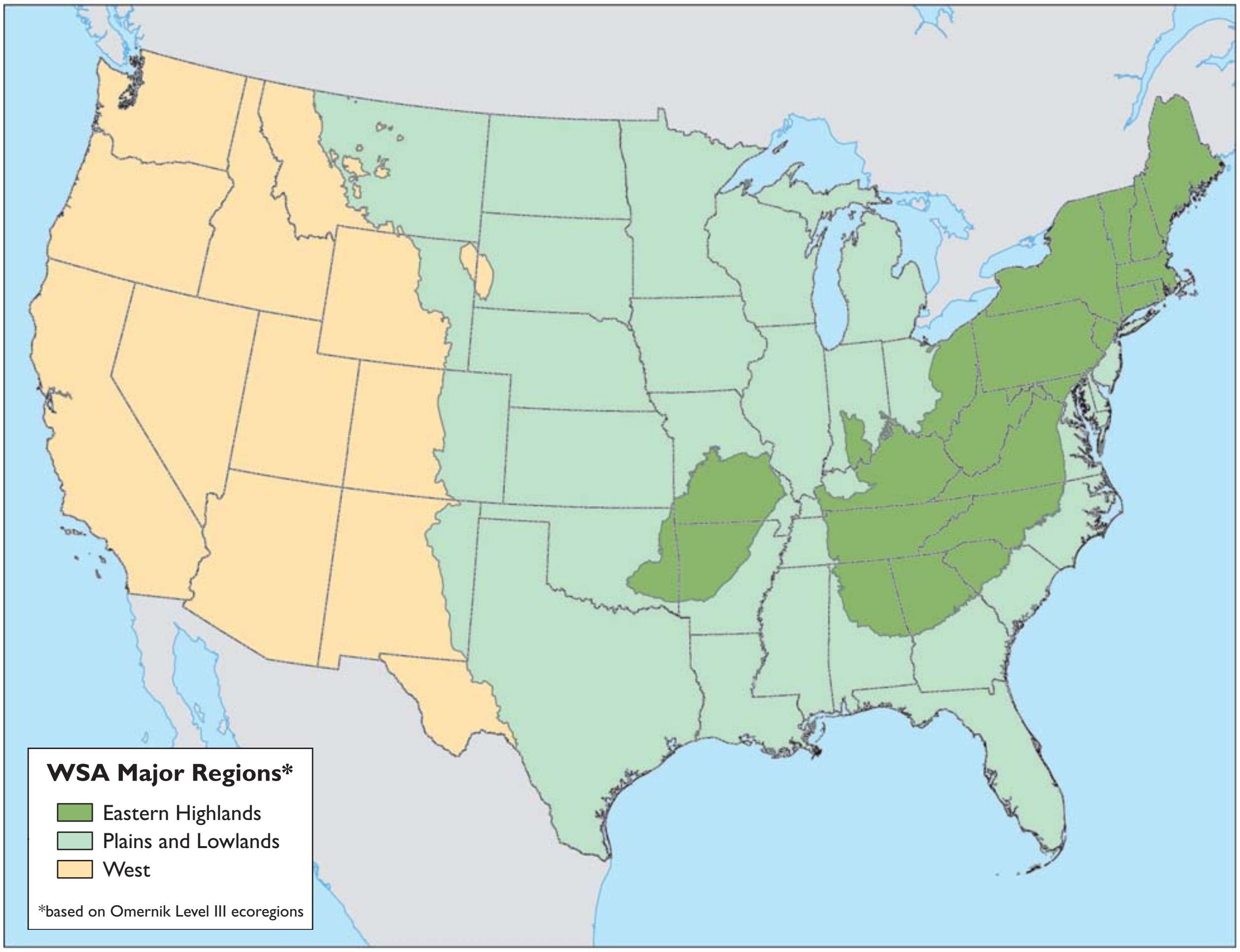
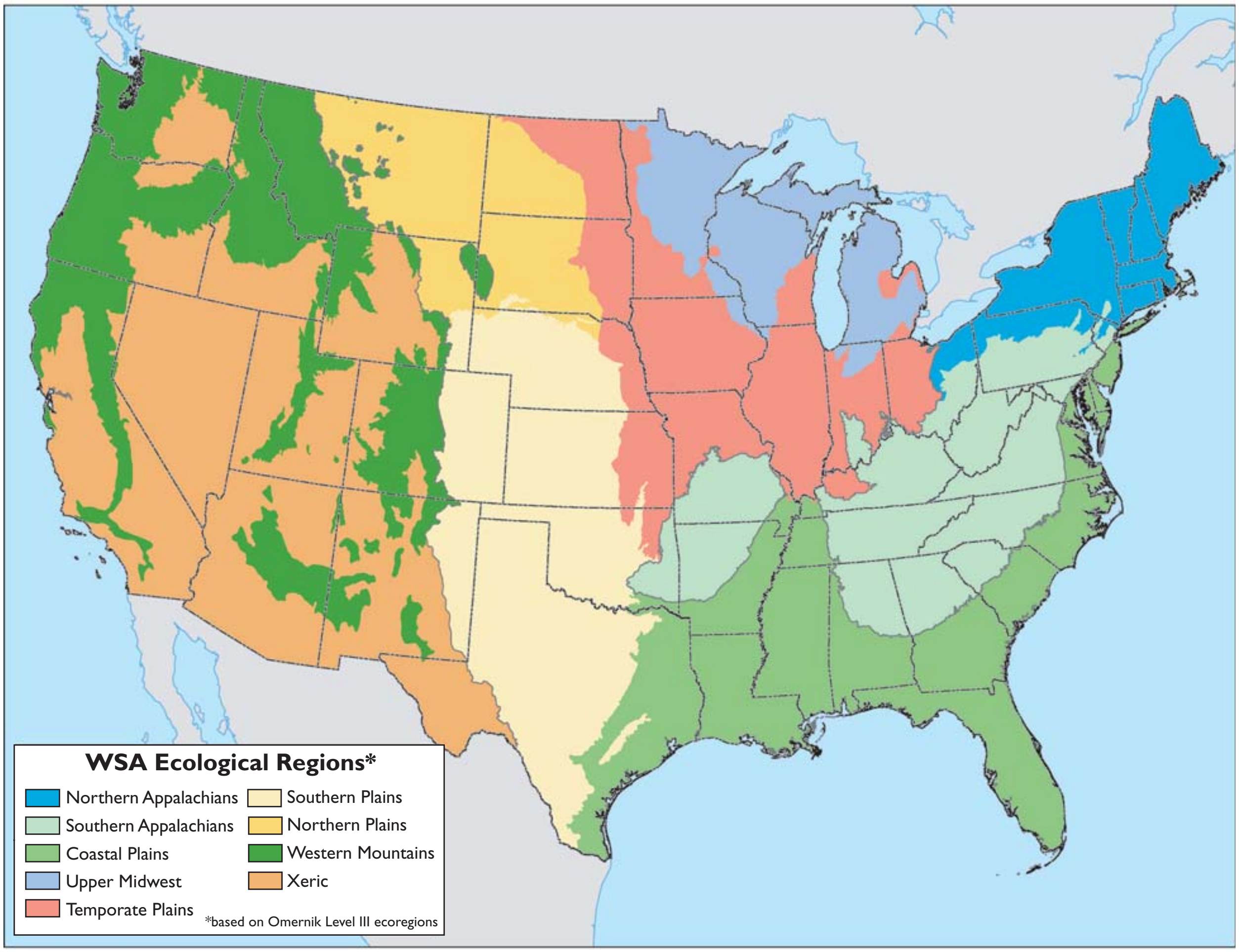


Figure 7. Three major regions were surveyed for the WSA (U.S. EPA/WSA).

A finer-scale reporting unit included in the WSA consists of nine ecological regions (ecoregions) (Figure 8) that further divide the three major regions. The three major regions and the nine ecoregions outlined in this report are aggregations of smaller ecoregions defined by EPA. Areas are included in an ecoregion based on similar landform and climate characteristics. For example, water resources within a particular ecoregion have similar natural characteristics and respond similarly to natural and anthropogenic stressors. Typically, management practices aimed at preventing degradation or restoring water quality apply to many flowing waters with similar problems throughout an ecoregion. This report presents results by ecoregions because the patterns of response to stress, and the stressors themselves, are often best understood in a regional context. The results for the nine ecoregions are reviewed in Chapter 3 of this report.

The Eastern Highlands region is divided into two ecoregions: the Northern Appalachians ecoregion, which encompasses New England, New York, and northern Pennsylvania, and the Southern Appalachians ecoregion, which extends from Pennsylvania into Alabama, through the eastern portion of the Ohio Valley, and includes the Ozark Mountains of Missouri, Arkansas, and Oklahoma.


WSA Ecological Regions*

*based on Omernik Level III ecoregions

Figure 8. Nine ecoregions were surveyed for the WSA (U.S. EPA/WSA).

The Plains and Lowlands region includes five WSA ecoregions: the Coastal Plains, the Upper Midwest, the Temperate Plains, the Northern Plains, and the Southern Plains. The Coastal Plains ecoregion covers the low-elevation areas of the East and Southeast, including the Atlantic and Gulf of Mexico coastal plains and the lowlands of the Mississippi Delta, which extend from the Gulf of Mexico northward through Memphis, TN. The Upper Midwest ecoregion is dominated by lakes and has little elevation gradient. The Temperate Plains ecoregion in the midwestern United States is probably most well-known as the Cornbelt. The Northern Plains and Southern Plains ecoregions are better known as the Great Prairies, with the Northern Plains ecoregion encompassing North Dakota, South Dakota, Montana, and northeast Wyoming, and the Southern Plains ecoregion encompassing parts of Nebraska, Kansas, Colorado, New Mexico, Oklahoma, and Texas.

The West region includes two WSA ecoregions: the Western Mountains ecoregion and the arid or Xeric ecoregion. The Western Mountains ecoregion includes the Cascade, Sierra Nevada, and Pacific Coast mountain ranges in the coastal states; the Gila Mountains in the southwestern states; and the Bitteroot and Rocky Mountains in the northern and central mountain states. The Xeric ecoregion includes both the true deserts and the arid lands of the Great Basin.

Some states participating in the WSA assessed an even finer state-scale resolution than the ecoregion scale by sampling additional random sites within their state borders. Although these data are included in the analysis described in this report, state-scale results are not presented for each state. These states are preparing similar analyses that reflect their respective water quality standards and regulations.

How Were Sampling Sites Chosen?

The WSA sampling locations were selected using modern survey design approaches. Sample surveys have been used in a variety of fields (e.g., election polls, monthly labor estimates, forest inventory analyses, National Wetlands Inventory) to determine the status of populations or resources of interest using a representative sample of a relatively few members or sites. This approach is especially cost effective if the population is so large that all components cannot be sampled or if obtaining a complete census of the resource is unnecessary to reach the desired level of precision for describing conditions.

Survey data are frequently reported in the news. For example, the percentage of children 1–5 years old living in the United States who have high lead levels in their blood is 2.2% +/- 1.2%, an estimate based on a random sample of children in the United States. The WSA results have similar rigor in their ability to estimate the percentage of stream miles, within a range of certainty, that are in good condition.

To pick a random sample, the location of members of the population of interest must be known. The target population for the WSA was the wadeable, perennial streams in the conterminous United States. The WSA design team used the National Hydrography Dataset (NHD)—a comprehensive set of digital spatial data on surface waters—to identify the location of wadeable, perennial streams. They also obtained information about stream order from the River Reach File, a related series of hydrographic databases that provide additional attributes about stream reaches. Using these resources, researchers determined the length of wadeable streams for each of the nine ecoregions (Figure 9).

For this WSA report, the wadeable stream miles assessed for the nation, regions, and ecoregions are referred to as the stream length. The total stream length represented in the WSA for the nation is 671,051 miles. For the Eastern Highlands, Plains and Lowlands, and West regions, the total stream length assessed for the WSA is 276,362 miles, 242,264 miles, and 152,425 miles, respectively.

The 1,392 sites sampled for the WSA were identified using a particular type of random sampling technique called a probability-based sample design, in which every element in the population has a known probability of being selected for sampling. This important feature ensures that the results of the WSA reflect the full range in character and variation among wadeable streams across the United States. Rules for site selection included weighting to provide balance in the number of stream sites from each of the 1st- through 5th-order size classes and controlled spatial distribution to ensure that sample sites were distributed across the United States (Figure 10).

The WSA sites were allocated by EPA Region and WSA ecoregion based on the distribution of 1st- through 5th-order streams within those regions. Within each EPA Region, random sites are more densely distributed where the perennial 1st- through 5th-order streams are more densely located and more sparsely distributed where streams are sparse. For example, EPA Region 4 in the southeastern United States includes large portions of the Southern Appalachian and Coastal Plains ecoregions. The survey design in EPA Region 4 identified more sites in the Southern Appalachians ecoregion, where the stream length is 178,449 miles, than in the Coastal Plains ecoregion, where the stream length is 72,130 miles (see Figure 9).

The basic sampling design drew 50 sampling sites randomly distributed in each of the EPA Regions and WSA ecoregions. Some of the unusually dense site patterns visible on Figure 10 occur because some states opted to increase the intensity of random sampling throughout

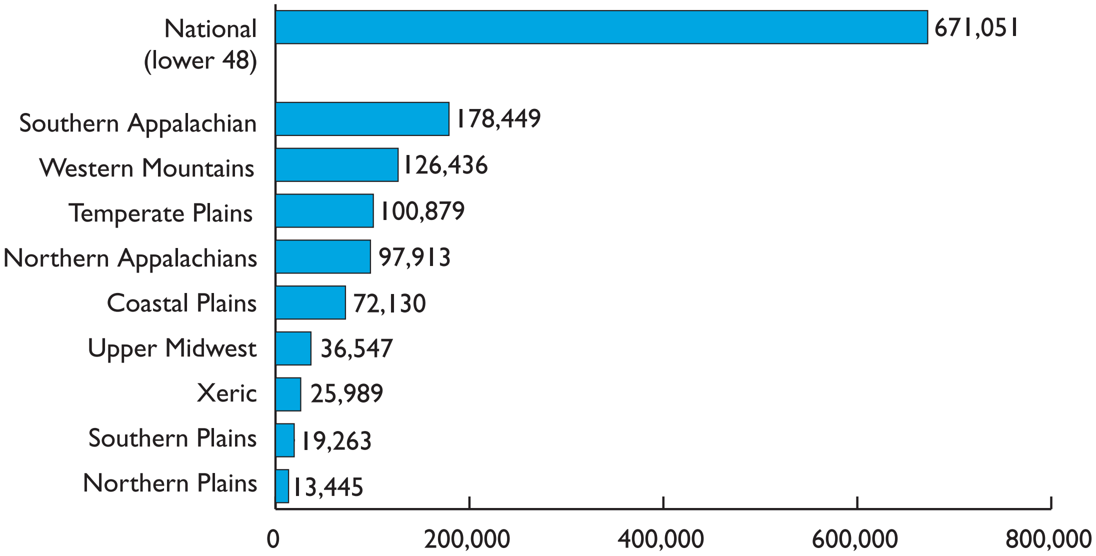


Figure 9. Length of wadeable, perennial streams in each WSA ecoregion (U.S. EPA/WSA).

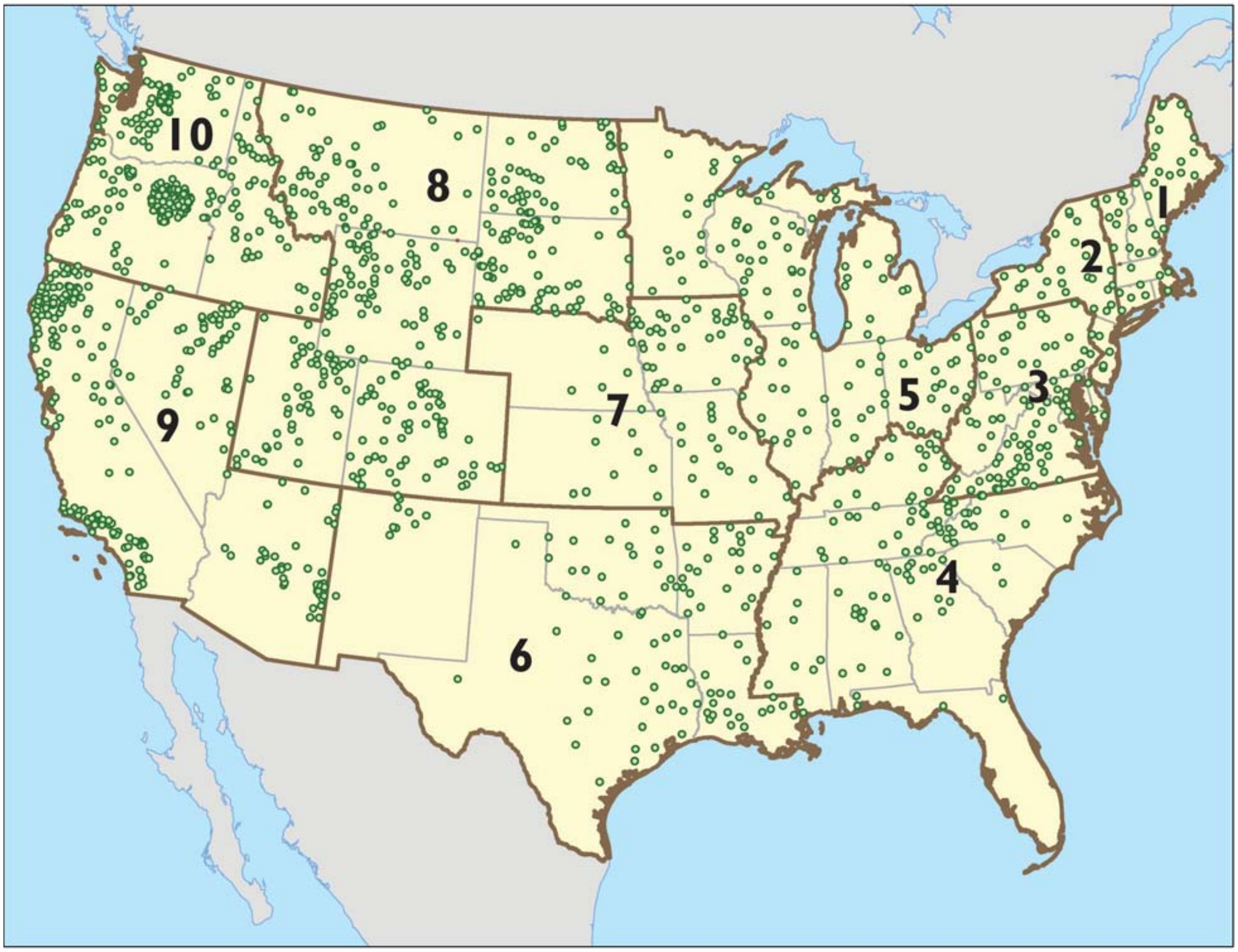


Figure 10. Sites sampled for the WSA by EPA Region (U.S. EPA/WSA).

their state to characterize statewide conditions. Fifteen states, including all states in EPA Regions 8, 9, and 10, increased the number of random sites to 50 sites throughout each state to support state-scale characterizations of stream condition. States also added clusters of random sites to characterize areas of special interest in Washington, Oregon, and California. When sites from an area of intensification were used in the ecoregion assessments, the weights associated with those sites were adjusted so that the additional sites did not dominate the results. The unbiased site selection of the survey design ensures that assessment results represent the condition of the streams throughout the nation.

An additional 150 reserve replacement sites were generated for each of the 10 EPA Regions. These replacement sites were used when site reconnaissance activities documented that one of the original stream sites could not be sampled. For example, sites were replaced when a waterbody did not meet the definition of a wadeable stream (e.g., no flowing water over 50% of the reach) or was unsafe for sampling, or when access to the stream was denied by the landowner.

Highlight

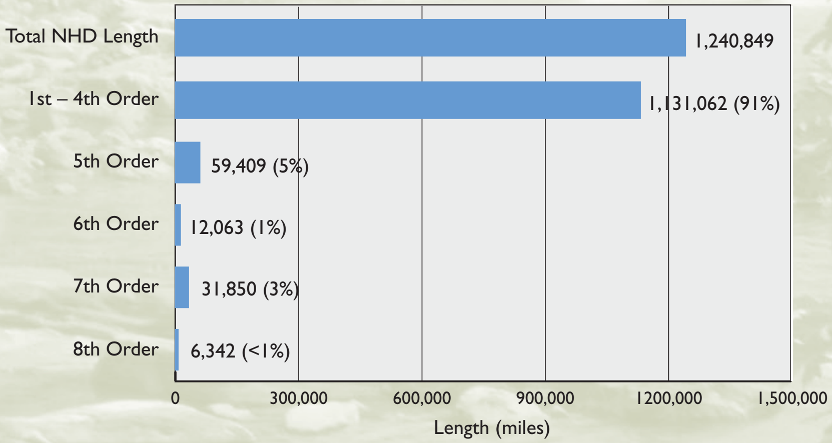
WSA Sampling Frame

The basis of the WSA target population is 1st- through 5th-order perennial streams, which are the streams most likely to be wadeable. The sampling frame used to represent the target population and to select the sites for the WSA is based on the perennial stream network contained in the USGS-EPA NHD. The NHD is a digitized version of 1:100K USGS topographic maps and shows both perennial and non-perennial (e.g., intermittent and ephemeral) streams.

The total stream length in the NHD stream and river network labeled perennial in the conterminous United States is 1,204,859 miles. Of this amount, 1,131,062 miles are 1st- through 4th-order streams, which make up 91% of the total stream length of the nation's flowing waters (see figure below).

Of the more than 1 million miles of stream length labeled as perennial, almost 34% (400,000 miles) were found to be non-perennial or non-target waterbodies (e.g., wetlands, reservoirs, irrigation canals). The remaining target stream length represents the portion of the NHD that meets criteria for inclusion in the WSA (e.g., perennial, wadeable streams). A portion of that target stream length was not sampled for various reasons, including denial of access by a landowner or inaccessibility.

In addition to generating results on the condition of perennial streams, the WSA provides data on the total length of perennial stream miles in the United States. These results will be loaded into the NHD so that the database is updated on the status of perennial/non-perennial stream information.



Estimate of perennial length of streams and rivers from the NHD (U.S. EPA/WSA). The 1st- through 4th-order streams comprise 91% of total estimated stream length in the NHD. The 1st- through 5th-order streams form the basis for the sampling design frame for the WSA.

How Were Waters Assessed?

Each WSA site was sampled by a two- to four-person field crew between 2000 and 2004 during a summer index period. More than 40 trained crews, comprised primarily of state environmental staff, sampled 1,392 stream sites using standardized field protocols. The field protocols were designed to consistently collect data relevant to the biological condition of stream resources and the resources' key stressors.

During each site visit, crews laid out the sample reach and the numerous transects to guide data collection (Figure 11). Field crews sent water samples to a laboratory for basic chemical analysis, whereas biological samples collected from 11 transects along each stream reach were sent to taxonomists for identification of macroinvertebrates. Crews also completed roughly 35 pages of field forms, recording data and information about the physical characteristics

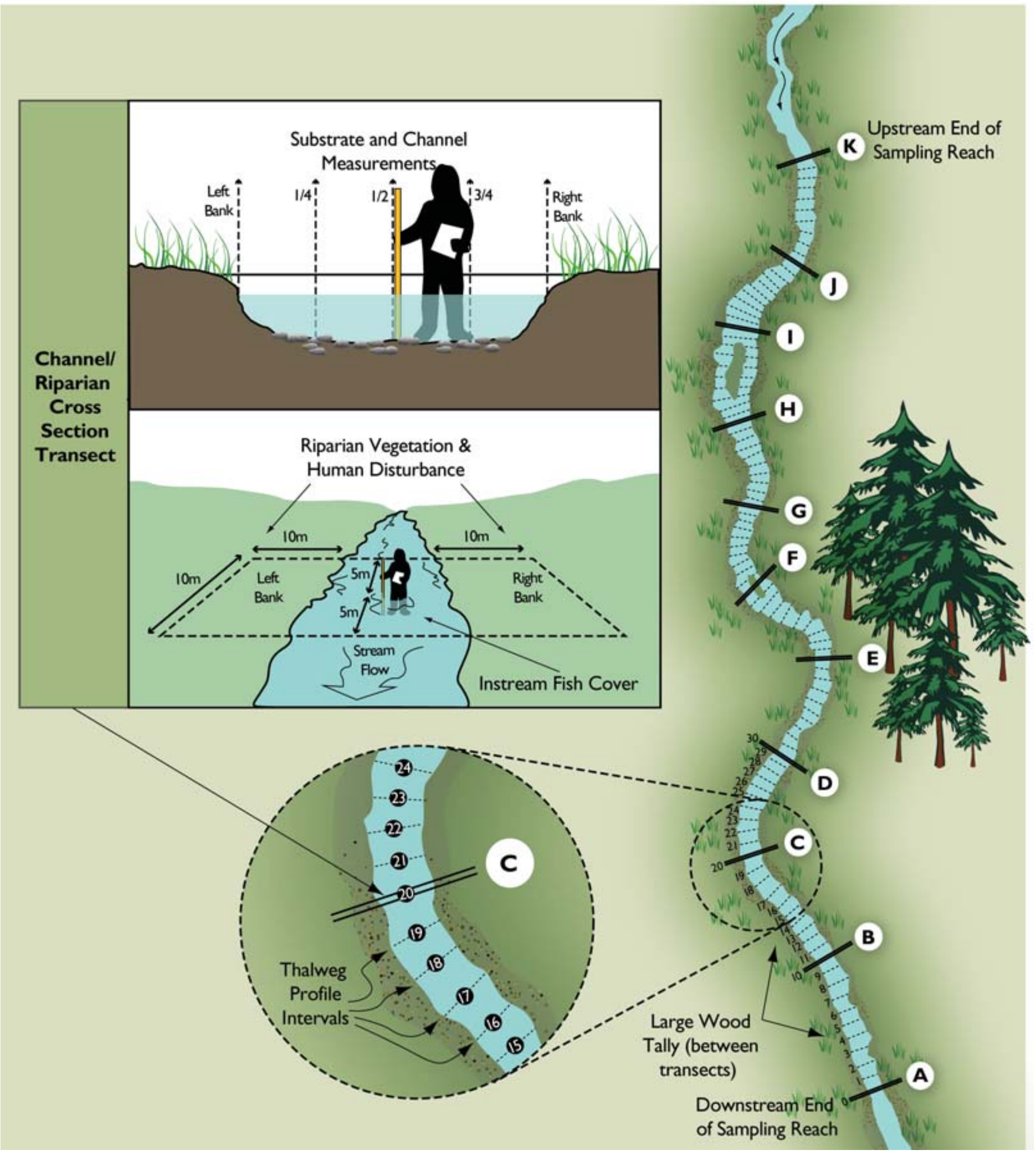


Figure 11. Reach layout for sampling (U.S. EPA/WSA).

of each stream and the riparian area adjacent to its banks. Each crew was audited, and 10% of the sites were revisited as part of the quality assurance plan for the survey.

The use of standardized field and laboratory protocols for sampling is a key feature of the WSA. Because ecologists use a range of methods to sample streams, it is often difficult to compare data collected by different states, regions, or agencies on a regional or national level. Standardization allows the data to be combined to produce a nationally consistent assessment. In addition to collecting a national set of consistent data, this nationwide sampling effort provided an opportunity to examine the comparability of different sample protocols by applying both the WSA method and various state or USGS methods to a subset of the sites. A separate analysis is underway to examine the comparability of these methods and explore options for how the resulting data may be used together.

The WSA uses benthic macroinvertebrates (e.g., aquatic larval stages of insects, crustaceans, worms, mollusks) as the biological indicator of a stream's ecological condition. Benthic macroinvertebrates live throughout the stream bed, attaching to rocks and woody debris and burrowing in sandy stream bottoms and among the debris, roots, and grasses that collect and grow along the water's edge (Figure 12). The

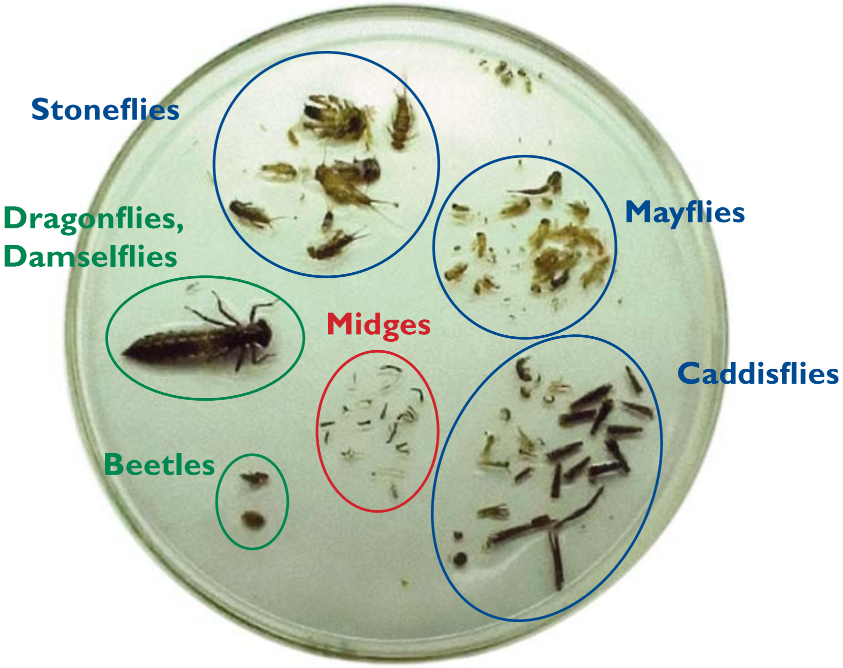


Figure 12. Stream macroinvertebrates (Photo courtesy of Maine Department of Environmental Protection). Macroinvertebrates in streams serve as the basis for the indicators of biological condition for the WSA.

WSA focuses on these macroinvertebrates because of their inherent capacity to integrate the effects of the stressors to which they are exposed, in combination and over time. Stream macroinvertebrates generally cannot move very quickly or very far; therefore, they are affected by, and may recover from, a number of changes in physical conditions (e.g., habitat loss), chemical conditions (e.g., excess nutrients), and biological conditions (e.g., the presence of invasive or non-native species). Some types of macroinvertebrates are affected by these conditions more than others.

Macroinvertebrates provide a measurement of biological condition or health relative to the biological integrity of a stream. Biological integrity represents the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region. Macroinvertebrates are researched by almost every state and federal program that monitors streams and are also increasingly evaluated by volunteer organizations that monitor water quality. In addition, water quality monitoring and management programs are enhancing the understanding of the biological condition of streams by adding other biological assemblages, including fish and algae.

The WSA supplements information on the biological condition of streams with measurements of key stressors that might negatively influence or affect stream condition. Stressors are the chemical, physical, and biological components of the ecosystem that have the potential to degrade stream biology. Some stressors are naturally occurring, whereas others result only from human activities, although most come from both sources.

Most physical stressors are created when we modify the physical habitat of a stream or its watershed, such as through extensive urban or agricultural development, excessive upland or bank erosion, or loss of streamside trees and vegetation. Examples of chemical stressors include toxic compounds (e.g., heavy metals, pesticides), excess nutrients (e.g., nitrogen and phosphorus), or acidity from acidic deposition or mine drainage. Biological stressors are characteristics of the biota that can influence biological integrity, such as the proliferation of non-native or invasive species (either in the streams and rivers, or in the riparian areas adjacent to these waterbodies).

The WSA water chemistry data allow an evaluation of the distribution of nutrients, salinity, and acidification in U.S. streams. The physical habitat data provide information on the prevalence of excess sediments, the quality of in-stream fish habitat, and the quality of riparian habitat alongside streams. Although these are among the key stressors identified by states as affecting water quality, they do not reflect the full range of potential stressors that can impact water quality. Future water quality surveys will include an assessment of additional stressors.

One of the key components of an ecological assessment is a measure of how important (e.g., how common) each stressor is within a region and how severely it affects biological condition. In addition to looking at the extent of streams affected by key stressors, the WSA evaluated the relative risk posed by key stressors to biological condition.

Highlight

Understanding Biological Condition

The main goal of the WSA is to develop a baseline understanding of the biological condition of our nation's streams. Why is this important?

One of the most meaningful ways to answer basic questions about water quality is to directly observe the communities of plants and animals that live in waterbodies. Aquatic plants and animals—especially the small creatures that are the focus of this study—are constantly exposed to the effects of various stressors; therefore, they reflect not only current conditions, but also the cumulative impacts of stresses and changes in conditions over time.

Benthic macroinvertebrates are widely used to determine biological condition. These organisms can be found in all streams, even in the smallest streams that cannot support fish. Because they are relatively stationary and cannot escape pollution, macroinvertebrate communities integrate the effects of stressors over time (i.e., pollution-tolerant species will survive in degraded conditions, and pollution-intolerant species will die). These communities are also critically important to fish because most game and non-game species require a good supply of benthic macroinvertebrates as food. Biologists have been studying the health and composition of benthic macroinvertebrate communities in streams for decades.

Biological condition is the most comprehensive indicator of waterbody health; when the biology of a stream is healthy, the chemical and physical components of the stream are also typically in good condition. In fact, several states have found that biological data frequently detect stream impairment where chemistry data do not.

Data on biological condition are invaluable for managing the nation's aquatic resources and ecosystems. Water quality managers can use these data to set protection and restoration goals, decide which indicators to monitor and how to interpret monitoring results, identify stresses to the waterbody and decide how they should be controlled, and assess and report on the effectiveness of management actions. In fact, many specific state responsibilities under the CWA—such as determining the extent to which waters support aquatic life uses, evaluating cumulative impacts from polluted runoff, and determining the effectiveness of discharger permit controls—are tied directly to an understanding of biological condition.

Setting Expectations

To interpret the data collected and assess current ecological condition, chemical, physical, and biological measurements must be compared to a benchmark or estimate of what one would expect to find in a natural condition. Setting reasonable expectations for an indicator is one of the greatest challenges to making an assessment of ecological condition. Should we take an historical perspective and try to compare current conditions to an estimate of pre-colonial conditions, pre-industrial conditions, or conditions at some other point in history, or should we accept that some level of anthropogenic disturbance is expected and simply use the best of today's conditions as the benchmark against which everything else is compared?

These questions, and their answers, all relate to the concept of reference condition. What do we use as a reference condition to set the benchmark for assessing the current status of these waterbodies? Because of the difficulty of estimating historical conditions for many of the WSA indicators, the assessment used the conditions at a collection of "least-disturbed" sites as the reference condition. This means that the condition at these sites represents the best available chemical, physical, and biological habitat conditions given the current state of the landscape. Least-disturbed sites were identified by evaluating data collected at sites according to a set of explicit screening levels that define what is least disturbed by human activities. To reflect the natural variability across the American landscape, these levels varied among the nine ecoregions. The WSA compared physical and chemical data collected at each site (e.g., nutrients, riparian condition, chloride, turbidity, fine sediments) to the screening levels to determine whether any given site was in least-disturbed condition for its ecoregion.

A researcher collects macroinvertebrate samples from a small stream in the Northern Appalachians ecoregion (Photo courtesy of the Vermont Department of Environmental Conservation).

Data on land use in the watersheds were not used to screen-out sites. For example, sites in agricultural areas with effective best management practices (BMPs) may have been considered least disturbed, provided they exhibited chemical and physical conditions that were among the best for their region. The WSA also did not use data on biological assemblages as a screening factor to select reference sites because that would have pre-judged expectations for biological condition. Similarly, when selecting least-disturbed reference sites for each stressor, the WSA excluded the specific stressors themselves from the screening process.

The WSA screening process resulted in the identification of a set of least-disturbed reference sites for each WSA ecoregion. These sites were distributed throughout the ecoregions and covered the range of natural variability across each area. Some of these sites included a degree of human-caused variability.

The results from samples collected at the reference sites for the various indicators (e.g., biological condition, nutrients) represent the range of expected values for least-disturbed reference condition. The WSA used this reference distribution as a benchmark for setting thresholds between good, fair, and poor condition. These thresholds were then applied to the random sites to generate the percentage of stream length in each condition class.

The WSA's approach examined the range of values for indicators in all of the reference sites in a region and used the 5th percentile of the reference distribution for that indicator to separate the poor sites from fair sites. Using the 5th percentile means that stream sites and associated stream length in poor condition were worse than 95% of the sites used to define least-disturbed reference condition. Similarly, the 25th percentile of the reference distribution was used to distinguish between sites in fair and good condition. This means that stream length reported as being in good condition was as good as or better than 75% of the sites used to define least-disturbed reference condition.

Within the reference site population, there exist two sources of variability: natural variability and variability due to human activities. Natural variability—the wide range of habitat types naturally found within each ecoregion—creates a spread of reference sites representing these differing habitats. Capturing natural variability in reference sites helps establish reference conditions that represent the range of environments in the ecoregions.

The second source of variation within the reference population is change resulting from human activities. Many areas in the United States have been altered, with natural landscapes transformed by cities, suburban sprawl, agricultural development, and resource extraction. The extent of those disturbances varies across regions. Some of the regions of the country have reference sites in watersheds with little to no evidence of human impact, such as mountain streams or streams in areas with very low population densities. Other regions of the country have few sites that have not been influenced by human activities. The least-disturbed reference sites in these widely influenced watersheds display more variability in quality than those in watersheds with little human disturbance.

Variation within the reference distribution due to disturbance was addressed before benchmarks were set for the condition classes of good, fair, and poor. For regions where the reference sites exhibited a disturbance signal, the data analysis team accounted for this disturbance by shifting the mean of the distribution toward the less-disturbed reference sites.

At a national meeting to discuss data analysis options, WSA collaborators supported this reference condition-based approach, which is consistent with EPA guidance and state practice on the development of biological and nutrient criteria. Additional details on how the least-disturbed condition and benchmarks for the condition categories were established for the WSA can be found in the data analysis method available on the EPA Web site at http://www.epa.gov/owow/streamsurvey.

Chapter 2

Photo courtesy of the Georgia Department of Natural Resources

Condition of the Nation's Streams

Condition of the Nation's Streams

Background

The CWA explicitly aims "to restore and maintain the chemical, physical, and biological integrity of the nation's waters." The WSA examines these three aspects of water quality through a small set of commonly used and widely accepted indicators. Although this WSA report does not include all aspects of biological integrity or review all possible chemical, physical, or biological stressors known to affect water quality, it does present the results of important indicators for an entire class of water resources—wadeable, perennial streams.

This chapter describes the results of the WSA and is organized as follows:

- **Indicators of Biological Condition** – Provides a description of the indicators or attributes of biological condition that were measured by the WSA survey and the results of the data analysis.
- **Aquatic Indicators of Stress** – Presents findings on the stressors evaluated for the study.
- **Ranking of Stressors** – Presents an analysis of the relative importance of the stressors in affecting biological condition.

Results for each indicator are shown for the nation's streams and for the three major regions (Eastern Highlands, Plains and Lowlands, and West). Chapter 3 of this report presents indicator results for each of the nine WSA ecoregions.

Indicators of Biological Condition

Ecologists evaluate the biological condition of water resources, including wadeable streams, by analyzing key characteristics of the communities of organisms that live in these waterbodies. These characteristics include the composition and relative abundance of key groups of animals (e.g., fish and invertebrates) and plants (e.g., periphyton, or algae that attach themselves to stream bottoms, rocks, and woody debris)

Jellison Meadow Brook, ME, in the Eastern Highlands region
(Photo courtesy of Colin Hill, Tetra Tech, Inc.).

found in streams. The WSA focused on just one assemblage, benthic macroinvertebrates (e.g., aquatic insects, crustaceans, worms and mollusks); however, some WSA participants also researched other assemblages.

Why focus on macroinvertebrates? Macroinvertebrates are key organisms that reflect the quality of their environment and respond to human disturbance in fairly predictable ways. As all fly-fishermen know, the insects emerging from streams and rivers are good indicators of the water quality and serve as an important food source for both game and non-game fish. Given the wide geographic distribution of macroinvertebrates, as well as their abundance and link to fish and other aquatic vertebrates, these organisms serve as excellent indicators of the quality of flowing waters and the human stressors that affect these systems.

WSA researchers collected samples of these organisms and sent them to laboratories for analysis, yielding a data set that provided the types and number of taxa (i.e., classifications or groupings of organisms) found at each site. To interpret this data set, the WSA used two indicators of biological condition: the Macroinvertebrate Index of Biotic Condition and the Observed/Expected (O/E) Ratio of Taxa Loss.

Macroinvertebrate Index of Biotic Condition

The Macroinvertebrate Index of Biotic Condition (henceforth referred to as the Macroinvertebrate Index) is similar in concept to the economic Consumer Confidence Index (or the Leading Index of Economic Indicators) in that the total index score is the sum of scores for a variety of individual measures, also called indicators or metrics. To determine the Leading Index, economists look at a number of metrics, including manufacturers' new orders for consumer goods, building permits, money supply, and other aspects of the economy that reflect economic growth. To determine the Macroinvertebrate Index, ecologists look at such metrics as taxonomic richness, habit and trophic composition, sensitivity to human disturbance, and other biotic aspects that reflect "naturalness." Originally developed as an Index of Biotic Integrity for fish in Midwestern streams, the Macroinvertebrate Index has been modified and applied to other regions, taxonomic groups, and ecosystems.

What are Taxa?

Taxa (plural of taxon) are groupings of living organisms, such as phylum, class, order, family, genus, or species. Biologists scientifically describe and organize organisms into taxa in order to better identify and understand them.

The metrics used to develop the Macroinvertebrate Index for the WSA covered six different characteristics of macroinvertebrate assemblages that are commonly used to evaluate biological condition:

- **Taxonomic richness** – This characteristic represents the number of distinct taxa, or groups of organisms, identified within a sample. Many different kinds of distinct taxa, particularly those that belong to pollution-sensitive insect groups, indicate a variety of physical habitats and food sources and an environment exposed to generally lower levels of stress.

Highlight

Using Multiple Biological Assemblages to Determine Biological Condition

EPA's guidance on developing biological assessment and criteria programs recommends the use of multiple biological assemblages to determine biological condition. The term "multiple biological assemblages" simply refers to the three main categories of life found in a waterbody: plants (e.g., algae), macroinvertebrates, and vertebrates (e.g., fish). The purpose of examining multiple biological assemblages is to generate a broader perspective of the condition of the aquatic resource of interest.

Each assemblage plays a different role in the way that rivers and streams function. Algae and macroinvertebrates occur throughout all types and sizes of streams, whereas very small streams may be naturally devoid of fish. Algae are the base of the food chain and capture light and nutrients to generate energy. They are sensitive to changes in shading, turbidity, and increases or decreases in nutrient levels. Macroinvertebrates feed on algae and other organic material that enters the aquatic system from the surrounding watershed. Macroinvertebrates also form the base of the food chain for many aquatic vertebrates. Fish are an example of these aquatic vertebrates and also serve as an important food source for people and wildlife. Each of these groups of aquatic organisms is sensitive in its own way to different human-induced disturbances.

The WSA collaboration began as a partnership among 12 western states; EPA Regions 8, 9, and 10; and EPA's Western Ecology Division (Environmental Monitoring and Assessment Program [EMAP] West) before it was expanded to include the entire United States. The original EMAP West program addressed fish, macroinvertebrates, and algae; future WSA reports will also address multiple assemblages.

To learn more about EMAP West and its use of multiple biological assemblages, visit www.epa.gov/emap/west/index.html.

- **Taxonomic composition** – Ecologists calculate composition metrics by identifying the different taxa groups, determining which taxa in the sample are ecologically important, and comparing the relative abundance of organisms in those taxa to the whole sample. Healthy stream systems have organisms from across many different taxa groups, whereas unhealthy stream systems are often dominated by a high abundance of organisms in a small number of taxa that are tolerant of pollution.
- **Taxonomic diversity** – Diversity metrics look at all the taxa groups and the distribution of organisms among those groups. Healthy streams should have a high level of diversity throughout the assemblage.
- **Feeding groups** – Many macroinvertebrates have specialized strategies to capture and process food from their aquatic environment. As a stream degrades from its natural condition, the distribution of animals among the different feeding groups will change. For example, as a stream loses its canopy (a source of leaves and shading), the aquatic community will shift from a more diverse food chain to one of predominantly algal-feeding animals that are tolerant of warm water.
- **Habits** – Just like other organisms, benthic macroinvertebrates are characterized by certain habits, including how they move and where they live. These habits are captured in the habit metrics. For example, some taxa burrow under the streambed sediment, whereas others cling to rocks and debris within the stream channel. A stream that naturally includes a diversity of habitat types will support animals with diverse habits; however, if a stream becomes laden with silt, the macroinvertebrates that cling, crawl, and swim will be replaced by those that burrow.
- **Pollution tolerance** – Each macroinvertebrate taxa can tolerate a specific range of stream contamination, which is referred to as their pollution tolerance. Once this level is exceeded, the taxa are no longer present in that area of the stream. Highly sensitive taxa, or those with a low pollution tolerance, are found only in streams with good water quality.

The specific metrics chosen for each of these categories varied among the nine ecoregions used in the analysis. Each metric was scored and then combined to create an overall Macroinvertebrate Index for each region, with values ranging from 0 to 100. For the WSA, analysts calculated a Macroinvertebrate Index score for each site, factored in the stream length represented by the site, and then generated an estimate of the stream length in a region, and nationally, with a given Macroinvertebrate Index score.

Six different characteristics of macroinvertebrate assemblages are commonly used to evaluate biological condition in wadeable streams (Photo courtesy of Lauren Holbrook, IAN Image Library).

Findings for the Macroinvertebrate Index of Biotic Condition

As illustrated in Figure 13, the Macroinvertebrate Index indicator results show that 42% of the nation's stream length (281,170 miles) is in poor condition, 25% (167,092 miles) is in fair condition, and 28% (189,236 miles) is in good condition compared to the least-disturbed reference condition in each of the nine WSA ecoregions. The 28% of stream length in good condition has conditions most similar to the reference distribution derived from the best-available (least-disturbed) sites in each ecoregion. The 5% (33,553 miles) of unassessed stream length results from the fact that 1st-order streams in New England were not sampled for the WSA.

Macroinvertebrate Index results show that the Eastern Highlands region has the highest proportion of stream length (52%, or 143,170 miles) in poor condition, followed by the Plains and Lowlands (40%, or 96,905 miles) and the West (27%, or 41,754 miles).

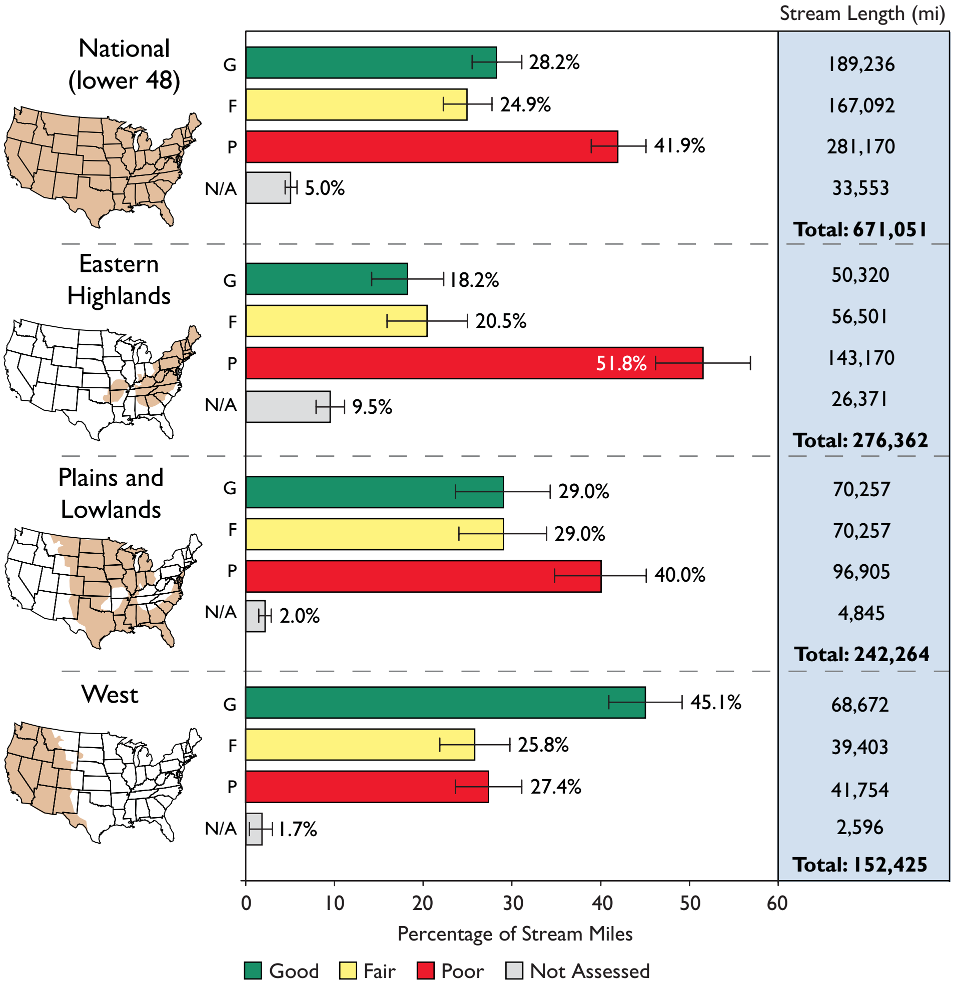


Figure 13. Biological condition of streams based on Macroinvertebrate Index of Biotic Condition (U.S. EPA/WSA). The Macroinvertebrate Index combines metrics of benthic community structure and function into a single index for each region. The thresholds for defining good, fair, and poor condition were developed for each of the nine WSA ecoregions based on condition at the least-disturbed reference sites. Stream length in good condition is most similar to least-disturbed reference condition; in fair condition has Macroinvertebrate Index scores worse than 75% of reference condition; and in poor condition has Macroinvertebrate Index scores worse than 95% of reference condition.

What are Confidence Intervals?

Confidence intervals (i.e., the small lines at the end of the bars in this report's charts) are provided to convey the level of certainty or confidence that can be placed in the information presented in this report. For example, for the national Macroinvertebrate Index, the WSA finds that 28.2% of the nation's stream length is in good condition, and the confidence is +/- 2.8%, which means that there is a 95% certainty that the real value is between 25.4% and 31%. The confidence interval depends primarily on the number of sites sampled; as more streams are sampled, the confidence interval becomes narrower, meaning there is more confidence in the findings. When fewer streams are sampled, the confidence interval become broader, meaning there is less certainty in the findings. Figure 13 shows an example of this pattern, in which the confidence interval for the national results (the largest sample size) is narrowest, whereas the confidence intervals for the major regions, where a smaller number of streams were sampled, are generally broader. Ultimately the breadth of the confidence interval is a tradeoff between the need for increased certainty to support decisions and the money and resources dedicated to monitoring.

Macroinvertebrate Observed/Expected (O/E) Ratio of Taxa Loss

The Macroinvertebrate O/E Ratio of Taxa Loss (henceforth referred to as O/E Taxa Loss) measures a specific aspect of biological health: taxa that have been lost at a site. The taxa expected (E) at individual sites are predicted from a model developed from data collected at least-disturbed reference sites; thus, the model allows a precise matching of sampled taxa with those that should occur under specific, natural environmental conditions. By comparing the list of taxa observed (O) at a site with those expected to occur, the proportion of expected taxa that have been lost can be quantified as the ratio of O/E. Originally developed for streams in the United Kingdom, O/E Taxa Loss models are modified for the specific natural conditions in each area for which they are used. The O/E Taxa Loss indicator is currently used by several countries and numerous states in the United States.

O/E Taxa Loss values range from 0 (none of the expected taxa are present) to slightly greater than 1 (more taxa are present than expected). These values are interpreted as the percentage of the expected taxa present. Each tenth of a point less than 1 represents a 10% loss of taxa at a site; thus, an O/E Taxa Loss score of 0.9 indicates that 90% of the expected taxa are present and 10% are missing. O/E Taxa Loss values must be interpreted in the context of the quality of reference sites used to build the predictive models, because the quality of reference sites available in a region sets the bar for what is expected (i.e., regions with lower-quality reference sites will have a lower bar). Although an O/E Taxa Loss value of 0.8 means the same thing regardless of a region (i.e., 20% of taxa have been lost relative to reference conditions in each region), the true amount of taxa loss will be underestimated if reference sites are of low quality.

The WSA developed three O/E Taxa Loss models to predict the extent of taxa loss across streams of the United States, one model for each of the three major regions outlined in this report (Eastern Highlands, Plains and Lowlands, West). Analysts used the O/E Taxa Loss scores observed at each site to generate estimates of the nation's stream length estimated to fall into four categories of taxa loss.

Although in many cases the results of O/E Taxa Loss analysis are similar to the results of the Macroinvertebrate Index, such agreement will not always occur. The O/E Taxa Loss indicator examines a specific aspect of biological condition (biodiversity loss), whereas the Macroinvertebrate Index combines multiple characteristics. For the WSA, the two indicators provided similar results in those WSA ecoregions that had a lower disturbance signal among their reference sites.

Findings for O/E Taxa Loss

Figure 14 displays the national and regional O/E Taxa Loss summary. These data are presented in four categories: (1) less than 10% taxa loss, (2) 10–20% taxa loss, (3) 20–50% taxa loss, and (4) more than 50% taxa loss. Forty-two percent of the nation's stream length retained more than 90% of expected taxa; 13% lost 10–20% of taxa; 26% lost 20–50% of taxa; and 13% lost more than 50% of taxa.

Within the three regions, stream length in the Eastern Highlands experienced the greatest loss of expected taxa, with 17% experiencing a loss of 50% or more. An additional 29% of stream length in this region lost 20–50% of taxa; 13% lost 10–20% of taxa; and only 28% of stream length lost fewer than 10% of taxa. Eleven percent of stream length in the Plains and Lowlands region experienced a taxa loss of 50% or more, 25% of stream length lost 20–50% of

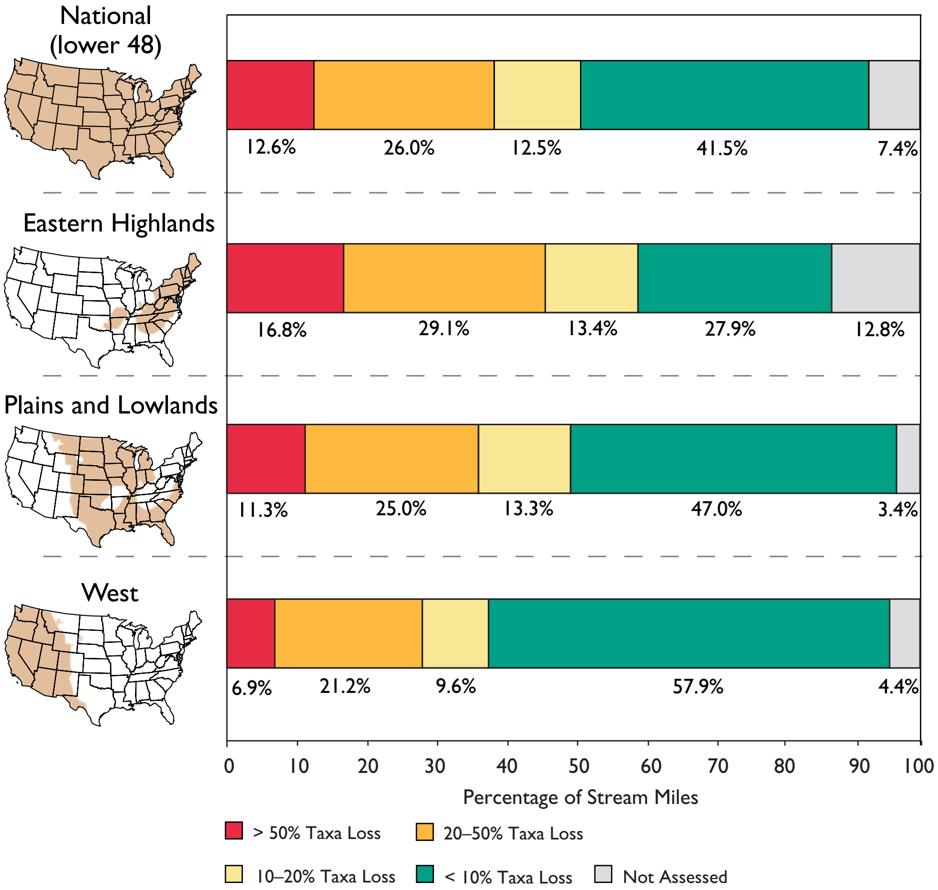


Figure 14. Macroinvertebrate taxa loss as measured by the O/E Ratio of Taxa Loss (U.S. EPA/WSA). The O/E Taxa Loss indicator displays the loss of taxa from a site compared to reference for that region. Scores 0.1 lower than reference represent a 10% loss in taxa.

taxa; 13% lost 10–20% of taxa; and 47% lost fewer than 10% of taxa. In the West, 7% of stream length experienced a taxa loss of 50% or more, 21% of stream length lost 20–50% of taxa; 10% lost 10–20% of taxa; and 58% of stream length lost less than 10% of taxa.

Aquatic Indicators of Stress

As people use the landscape, their actions can produce effects that are stressful to aquatic ecosystems. These aquatic stresses can be chemical, physical, or in some cases, biological. The WSA has selected a short list of stressors from each of these categories as indicators for assessment. This list is not intended to be all-inclusive, and in fact, some important stressors are not included because there is currently no way to assess them at the site scale (e.g., water withdrawals for irrigation). Future assessments of U.S. stream and river condition will include a more comprehensive list of stressors from each of these categories.

WSA indicators are based on direct measures of stress in the stream or adjacent riparian areas, not on land use or land cover alterations, such as row crops, mining, or grazing. Many human activities and land uses can be sources of one or more stressors to streams; however, the WSA only assesses stressors to determine the general condition of the resource and which stressors are most significant and does not track the source of these stressors. Source tracking, an expensive and time-consuming process, is a logical future step for the WSA and similar national assessments.

A summary of the national and regional results for indicators of chemical and physical habitat are shown in Figures 15 through 22. WSA results for these indicators for each of the nine WSA ecoregions are presented in Chapter 3 of this report.

Chemical Stressors

Four chemical stressors were assessed as indicators in the WSA: total phosphorus, total nitrogen, salinity, and acidification. These stressors were selected because of national or regional concerns about the extent to which each might be impacting the quality of stream biota. The thresholds for interpreting data were developed from a set of least-disturbed reference sites for each of the nine WSA ecoregions, as described in Chapter 1, *Setting Expectations*. The results for each ecoregion were tallied to report on conditions for the three major regions and the entire nation.

Total Phosphorus Concentrations

Phosphorus is usually considered the most likely nutrient limiting algal growth in U.S. freshwater waterbodies. Because of the naturally low concentrations of phosphorus in stream systems, even small increases in phosphorus concentrations can impact a stream's water quality. Some waters—such as streams originating from groundwater in volcanic areas of eastern Oregon and Idaho—have naturally higher concentrations of phosphorus. This natural variability is reflected in the regional thresholds for high, medium, and low, which are based on the least-disturbed reference sites for each of the nine WSA ecoregions.

Highlight

Nutrients and Eutrophication in Streams

Eutrophication is a condition characterized by excessive plant growth that results from high levels of nutrients in a waterbody. Although eutrophication is a natural process, human activities can accelerate this condition by increasing the rate at which nutrients and organic substances enter waters from their surrounding watersheds. Agricultural runoff, urban runoff, leaking septic systems, sewage discharges, eroded streambanks, and similar sources can increase the flow of nutrients and organic substances into streams, and subsequently, into downstream lakes and estuaries. These substances can overstimulate the growth of algae and aquatic plants, creating eutrophic conditions that interfere with recreation and the health and diversity of insects, fish, and other aquatic organisms.

Nutrient enrichment due to human activities has long been recognized as one of the leading problems facing our nation's lakes, reservoirs, and estuaries. It has also been more recently recognized as a contributing factor to stream degradation. In broadest terms, nutrient over-enrichment of streams is a problem because of the negative impacts on aquatic life (the focus of the WSA); adverse health effects on humans and domestic animals; aesthetic and recreational use impairment; and excessive nutrient input into downstream waterbodies, such as lakes.

Excess nutrients in streams can lead to excessive growth of phytoplankton (free-floating algae) in slow-moving rivers, periphyton (algae attached to the substrate) in shallow streams, and macrophytes (aquatic plants large enough to be visible to the naked eye) in all waters. Unsightly filamentous algae can impair the aesthetic enjoyment of streams. In more extreme situations, excessive growth of aquatic plants can slow water flow in flat streams and canals, interfere with swimming, snag fishing lures, and clog the screens on water intakes of water treatment plants and industries.

Nutrient enrichment in streams has also been demonstrated to affect animal communities in these waterbodies (see the References section at the end of this report for examples of published studies). For example, declines in invertebrate community structure have been correlated directly with increases in phosphorus concentration. High concentrations of nitrogen in the form of ammonia (NH_3) are known to be toxic to aquatic animals. Excessive levels of algae have also been shown to be damaging to invertebrates. Finally, fish and invertebrates will experience growth problems and can even die if either oxygen is depleted or pH increases are severe; both of these conditions are symptomatic of eutrophication.

As a system becomes more enriched by nutrients, different species of algae may spread and species composition can shift; however, unless such species shifts cause clearly demonstrable symptoms of poor water-quality—such as fish kills, toxic algae, or very long streamers of filamentous algae—the general public is unlikely to be aware of a potential ecological concern.

Phosphorus influx leads to increased algal growth, which reduces dissolved oxygen levels and water clarity within the stream. (See *Highlight: Nutrients and Eutrophication in Streams* for more information about the impacts of excess phosphorus and nitrogen.) Phosphorus is a common component of fertilizers, and high phosphorus concentrations in streams may be associated with poor agricultural practices, urban runoff, or point-source discharges (e.g., effluents from sewage treatment plants).

Findings for Total Phosphorus

Approximately 31% of the nation's stream length (207,355 miles) has high concentrations of phosphorus, 16% (108,039 miles) has medium concentrations, and 49% (327,473 miles) has low concentrations (Figure 15). Of the three major regions, the Eastern Highlands has the greatest proportion of stream length with high concentrations of phosphorus (43%, or 117,730 miles), followed by the Plains and Lowlands (25%, or 60,324 miles) and the West (19%, or 28,174 miles) regions.

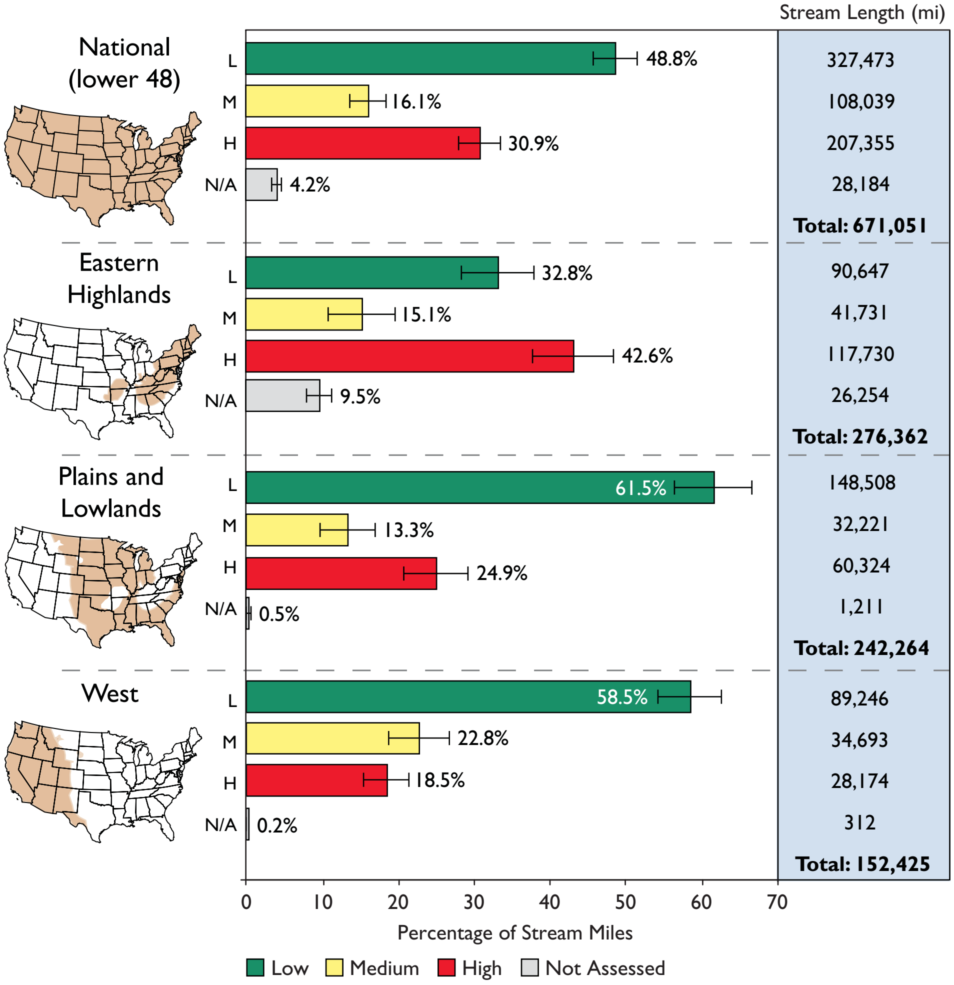


Figure 15. Total phosphorus concentrations in U.S. streams (U.S. EPA/WSA). Percent of stream length with low, medium, and high concentrations of phosphorus based on regionally relevant thresholds derived from the least-disturbed regional reference sites. Low concentrations are most similar to reference condition; medium concentrations are greater than the 75th percentile of reference condition; and high concentrations are greater than the 95th percentile of reference condition.

Total Nitrogen Concentrations

Nitrogen, another nutrient, is particularly important as a contributor to coastal and estuarine algal blooms. Nitrogen is the primary nutrient limiting algal growth in some regions of the United States, particularly in granitic or basaltic geology found in parts of the Northeast and the Pacific Northwest. Increased nitrogen inputs to a stream can stimulate growth of excess algae, such as periphyton, which results in low dissolved oxygen levels, a depletion of sunlight available to the streambed, and degraded habitat conditions for benthic macroinvertebrates and other aquatic life (see *Highlight: Nutrients and Eutrophication in Streams*). Common sources of excess nitrogen include fertilizers, wastewater, animal wastes, and atmospheric deposition.

Findings for Total Nitrogen

A significant portion of the nation's stream length (32%, or 213,394 miles) has high concentrations of nitrogen compared to least-disturbed reference conditions, 21% (138,908 miles) has medium concentrations, and 43% (290,565 miles) has relatively low concentrations (Figure 16). As with phosphorus, the Eastern

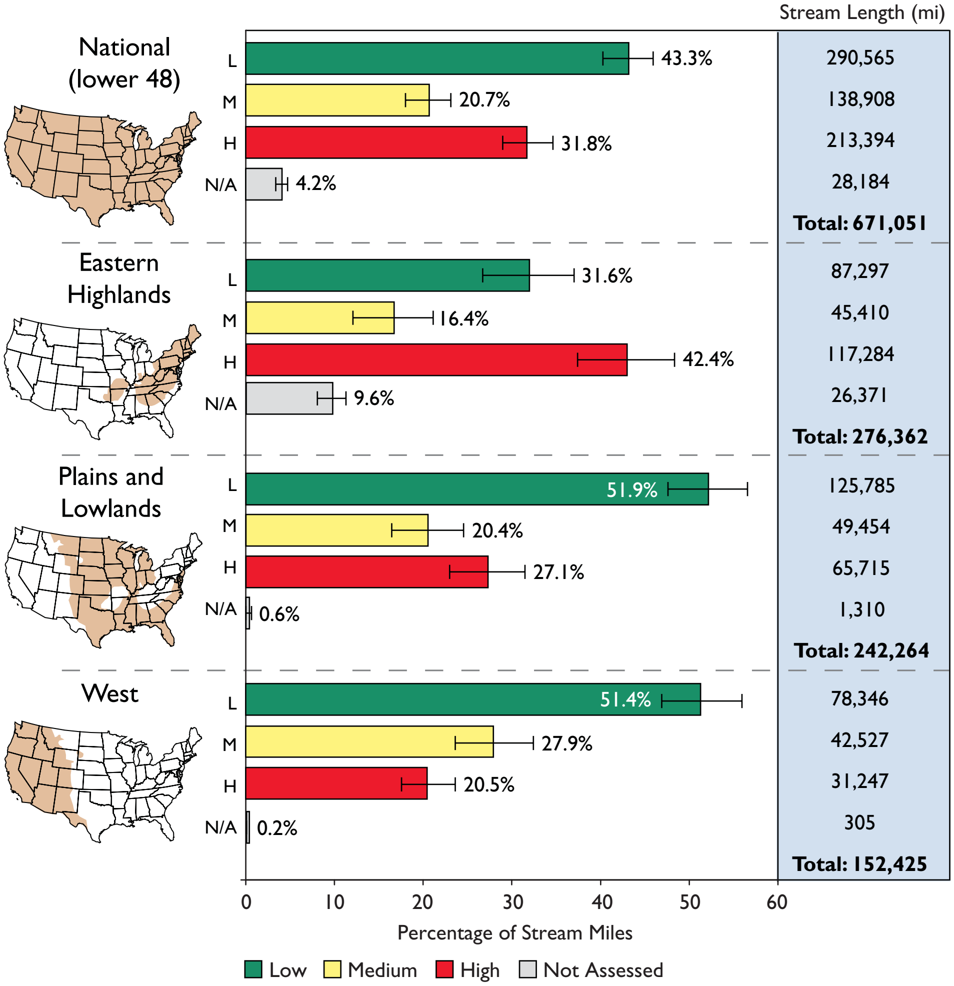


Figure 16. Total nitrogen concentrations in U.S. streams (U.S. EPA/WSA). Percent of stream length with low, medium, and high concentrations of nitrogen based on regionally relevant thresholds derived from the least-disturbed regional reference sites. Low concentrations are most similar to reference condition; medium concentrations are greater than the 75th percentile of reference condition; and high concentrations are greater than the 95th percentile of reference condition.

Highlands region has the greatest proportion of stream length with high concentrations of nitrogen (42%, or 117,284 miles), followed by the Plains and Lowlands (27%, or 65,715 miles) and the West (21%, or 31,247 miles).

Salinity

Excessive salinity occurs in areas with high evaporative losses of water and can be exacerbated by repeated use of water for irrigation or by water withdrawals. Both electrical conductivity and total dissolved solids (TDS) can be used as measures of salinity; however, conductivity was used for the WSA.

Findings for Salinity

Roughly 3% of the nation's stream length (19,889 miles) has high levels of salinity, 10% (69,585 miles) has medium levels, and 83% (553,530 miles) has low levels compared to levels found in least-disturbed reference sites for the nine WSA ecoregions (Figure 17). The Plains and Lowlands region has the greatest proportion of stream length with high levels of salinity (5%, or 12,113 miles), followed by the West (3%, or 4,009 miles) and Eastern Highlands (1%, or 3,593 miles).

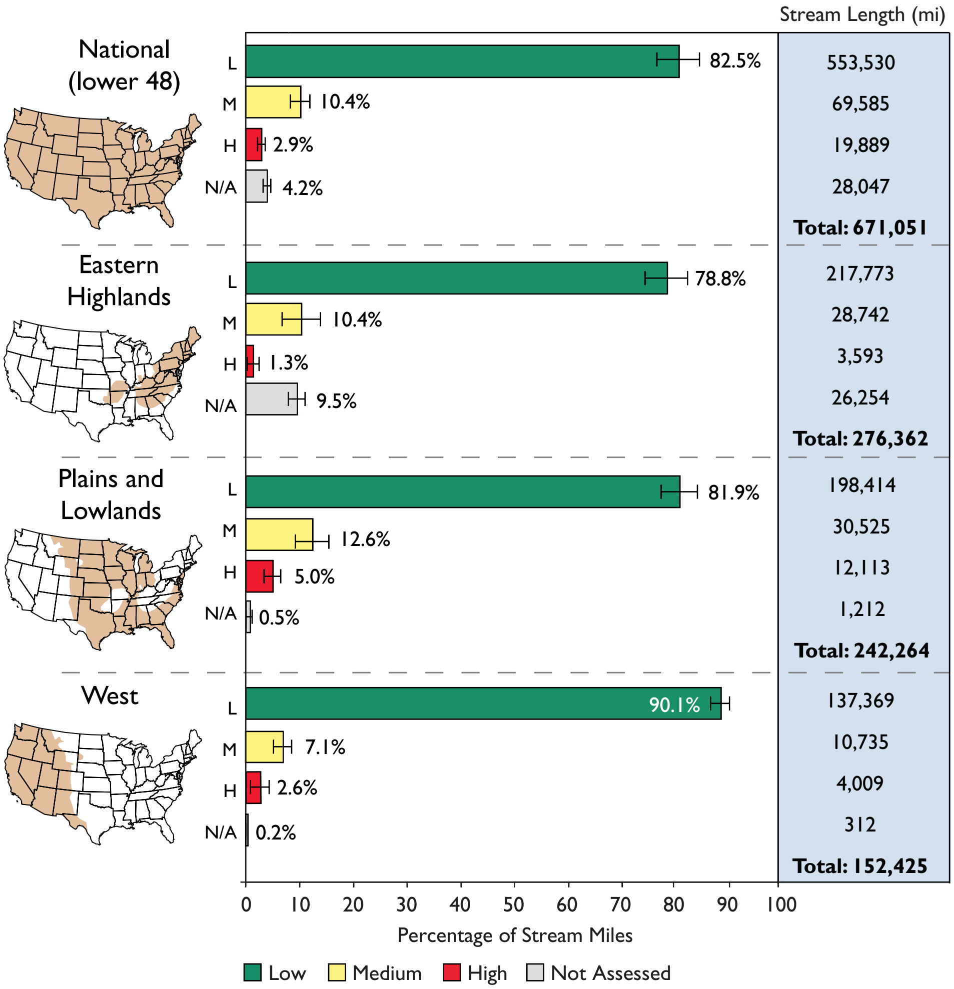


Figure 17. Salinity conditions in U.S. streams (U.S. EPA/WSA). This indicator is based on electrical conductivity measured in water samples. Thresholds are based on conditions at least-disturbed regional reference sites.

Acidification

Streams and rivers can become acidic through the effects of acid deposition (e.g., acid rain) or acid mine drainage, particularly from coal mining. Previous studies have shown that these issues, while of concern, tend to be focused in a few geographic regions of the country. Streams and rivers can also be acidic because of natural sources, such as high levels of dissolved organic compounds. The WSA identifies the extent of systems that are not acidic, naturally acidic (i.e., similar to reference), and acidic because of anthropogenic disturbance. This last category includes streams that are acidic because of deposition (either chronic or episodic) or because of mine drainage.

Acid rain forms when smokestack and automobile emissions (particularly sulfur dioxide and nitrogen oxides) combine with moisture in the air to form dilute solutions of sulfuric and nitric acid. Acid deposition can also occur in dry form, such as the particles that make up soot. When wet and dry deposition fall on sensitive watersheds, they can have deleterious effects on soils, vegetation, and streams and rivers.

In assessing acid rain's effects on flowing waters, the WSA relied on a measure of the water's ability to buffer inputs of acids, called acid-neutralizing capacity (ANC). When ANC values fall below zero, the water is considered acidic and can be either directly or indirectly toxic to biota (i.e., by mobilizing toxic metals, such as aluminum). When ANC is between 0 and 25 milliequilivents, the water is considered sensitive to episodic acidification during rainfall events. These threshold values were determined based on values derived from the National Acid Precipitation Assessment Program (NAPAP).

Acid mine drainage forms when water moves through mines and mine tailings, combining with sulfur released from certain minerals to form strong solutions of sulfuric acid and mobilize many toxic metals. As in the case of acid rain, the acidity of waters in mining areas can be assessed by using ANC values. Mine drainage also produces extremely high concentrations of sulfate—much higher than those found in acid rain. Although sulfate is not directly toxic to biota, it serves as an indicator of mining's influence on streams and rivers. When ANC values and sulfate concentrations are low, acidity can be attributed to acid rain. When ANC values are low and sulfate concentrations are high, acidity can be attributed to acid mine drainage. Mine drainage itself, even if not acidic, can harm aquatic life; however, the WSA does not include an assessment of the extent of mine drainage that is not acidic.

Acidic mine drainage forms when water moves through mines and mine tailings (Photo courtesy of Ben Fertig, IAN Image Library).

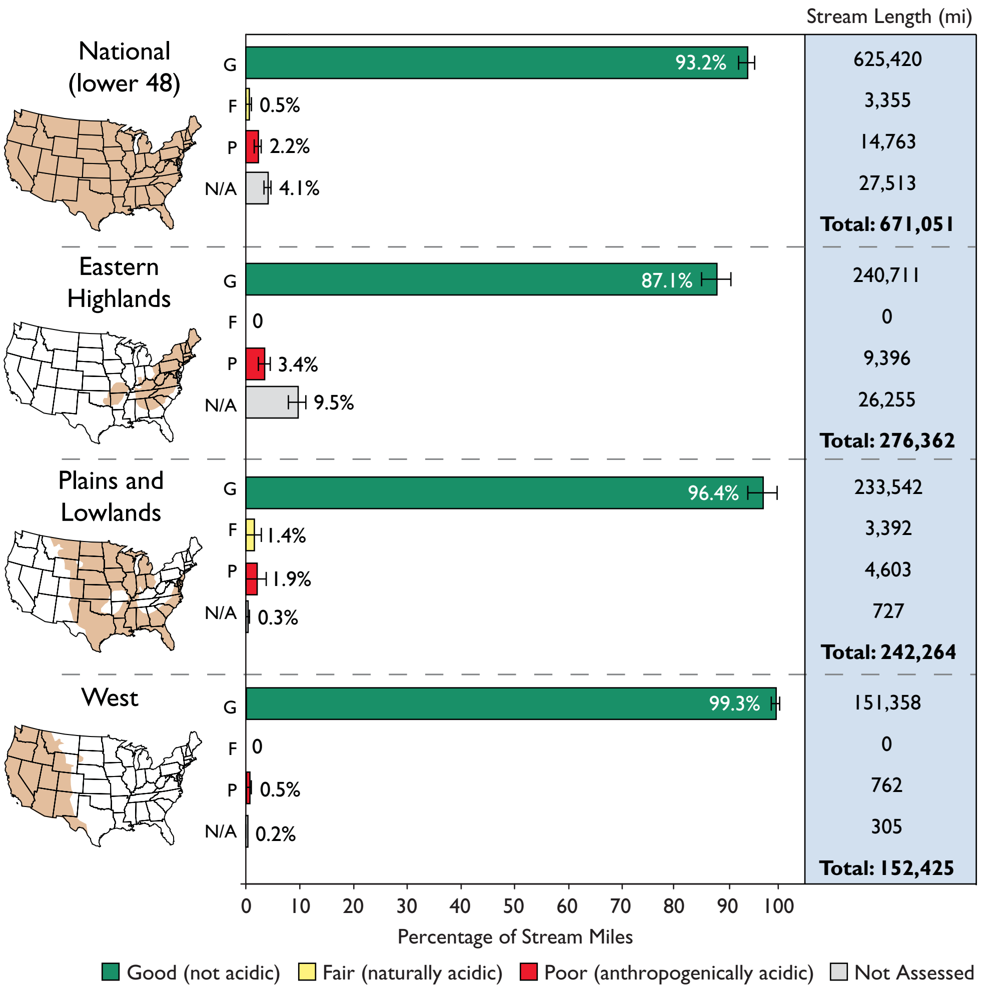


Figure 18. Acidification in U.S. streams (U.S. EPA/WSA). Streams are considered acidic when ANC values fall below zero. Streams are considered sensitive to acidification during rainfall events when ANC values are between 0 and 25 milliequilivents. Both ranges were scored as anthropogenically acidic in poor condition. Acidic streams with high concentrations of sulfate are associated with acid mine drainage, whereas low concentrations of sulfate indicate acidification due to acid rain.

Findings for Acidification

Figure 18 shows that about 2% of the nation's stream length (14,763 miles) is impacted by acidification from anthropogenic sources. These sources include acid deposition (0.7%), acid mine drainage (0.4%), and episodic acidicity due to high-runoff events (1%). Although these percentages appear relatively small, they reflect a significant impact in certain parts of the United States, particularly in the Eastern Highlands region, where 3% of the stream length (9,396 miles) is impacted by acidification.

Physical Habitat Stressors

A number of human activities can potentially impact the physical habitat of streams upon which the biota rely. Soil erosion from road construction, poor agricultural practices, and other disturbances can result in increases in the amount of fine sediment on the stream bottom; these sediments can negatively impact macroinvertebrates and fish. Physical alterations to vegetation along stream banks, alterations to the physical characteristics within the stream itself, and changes in the flow of water all have the potential to impact stream biota.

Although many aspects of stream and river habitats can become stressful to aquatic organisms when these aspects are modified, the WSA focuses on four specific stressors as habitat indicators: streambed sediments, in-stream fish habitat, riparian vegetation, and riparian disturbance.

Streambed Sediments

The supply of water and sediments from drainage areas affects the shape of river channels and the size of streambed particles in streams and rivers. One measure of the interplay between sediment supply and transport is relative bed stability (RBS). The measure of RBS used in the WSA is a ratio that compares measures of particle size of observed sediments to the size of sediments that each stream can move or scour during its flood stage (based on measures of the size, slope, and other physical characteristics of the stream channel). The expected RBS ratio differs naturally among regions, depending upon landscape characteristics, such as geology, topography, hydrology, natural vegetation, and natural disturbance history.

Values of the RBS ratio can be either substantially lower (e.g., finer, more unstable streambeds) or higher (e.g., coarser, more stable streambeds) than those expected, based on the range found at least-disturbed reference sites. Both high and low values are considered to be indicators of ecological stress. Excess fine sediments in a stream bed can destabilize streams when the supply of sediments from the landscape exceeds the ability of the stream to move them downstream. This imbalance results from a number of human uses of the landscape, including agriculture, road building, construction, and grazing. Streams with significantly more stable streambeds than reference condition (e.g., evidence of hardening and scouring, streams that have been lined with concrete) were not included in the assessment of this indicator. These stream conditions occurred so rarely in the survey that it was not necessary to separate them from the overall population. The WSA focuses on increases in streambed sediment levels, represented by lower-than-expected streambed stability as the indicator of concern.

Lower-than-expected streambed stability may result either from high inputs of fine sediments (e.g., erosion) or increases in flood magnitude or frequency (e.g., hydrologic alteration). When low RBS results from inputs of fine sediment, the sediment can fill in the habitat spaces between stream cobbles and boulders. The instability (low RBS) resulting from hydrologic alteration can be a precursor to channel incision and gully formation.

WSA researchers collected data on indicators of biological condition and aquatic indicators of stress at 1,392 wadeable stream locations in the conterminous United States (Photo courtesy of Tetra Tech, Inc.).

Findings for Streambed Sediments

Approximately 25% of the nation's stream length (167,092 miles) has streambed sediment characteristics in poor condition compared to regional reference condition (Figure 19). Streambed sediment characteristics are rated fair in 20% of the nation's stream length (132,197 miles) and good in 50% of stream length (336,196 miles) compared to reference condition. The two regions with the greatest percentage of stream length in poor condition for streambed sediment characteristics are the Eastern Highlands (28%, or 77,381 miles) and the Plains and Lowlands (26%, or 63,958 miles), whereas the West has the lowest percentage of stream length (17%, or 26,522 miles) in poor condition for this indicator.

In-stream Fish Habitat

The most diverse fish and macroinvertebrate assemblages are found in streams and rivers that have complex forms of habitat, such as boulders, undercut banks, tree roots, and large wood within the stream banks. Human use of streams and riparian areas often results in the simplification of this habitat, with potential effects on biological

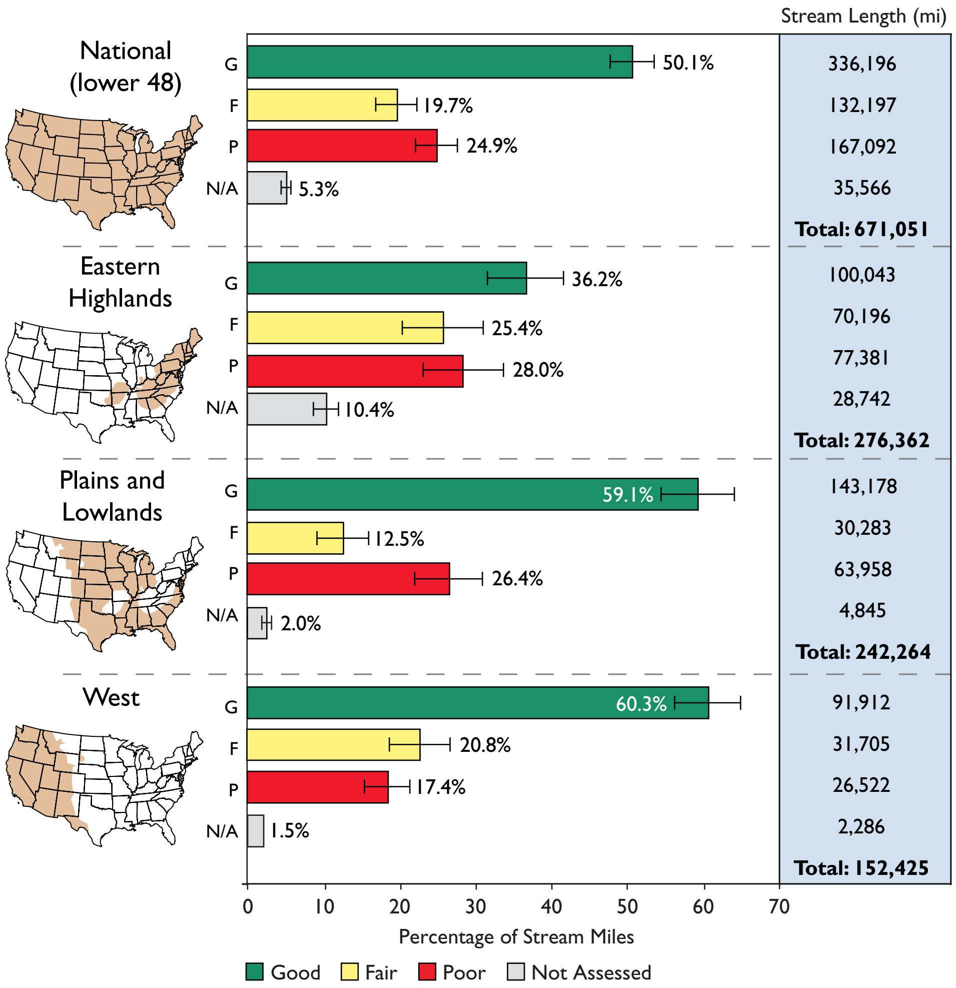


Figure 19. Streambed sediments in U.S. streams (U.S. EPA/WSA). This indicator measures the percentage of streambeds impacted by increased sedimentation, which indicates alteration from reference condition as defined by least-disturbed reference sites in each of the nine WSA ecoregions.

integrity. The WSA used a habitat complexity measure that sums the amount of in-stream fish concealment features and habitat consisting of undercut banks, boulders, large pieces of wood, brush, and cover from overhanging vegetation within a stream and its banks.

Findings for In-stream Fish Habitat

Twenty percent of the nation's stream length (130,928 miles) is in poor condition for in-stream fish habitat, 25% (166,851 miles) is in fair condition, and 52% (345,766 miles) is in good condition compared to least-disturbed reference condition (Figure 20). In the three major regions, the highest proportion of stream length in poor condition for in-stream habitat is in the Plains and Lowlands (37%, or 89,638 miles), whereas only 12% of stream length (18,748 miles) in the West and 8% of stream length (22,797 miles) in the Eastern Highlands region is rated poor for this indicator.

Riparian Vegetative Cover

The presence of complex, multi-layered vegetative cover in the corridor along a stream or river is a measure of how well the stream network is buffered against sources of stress in the

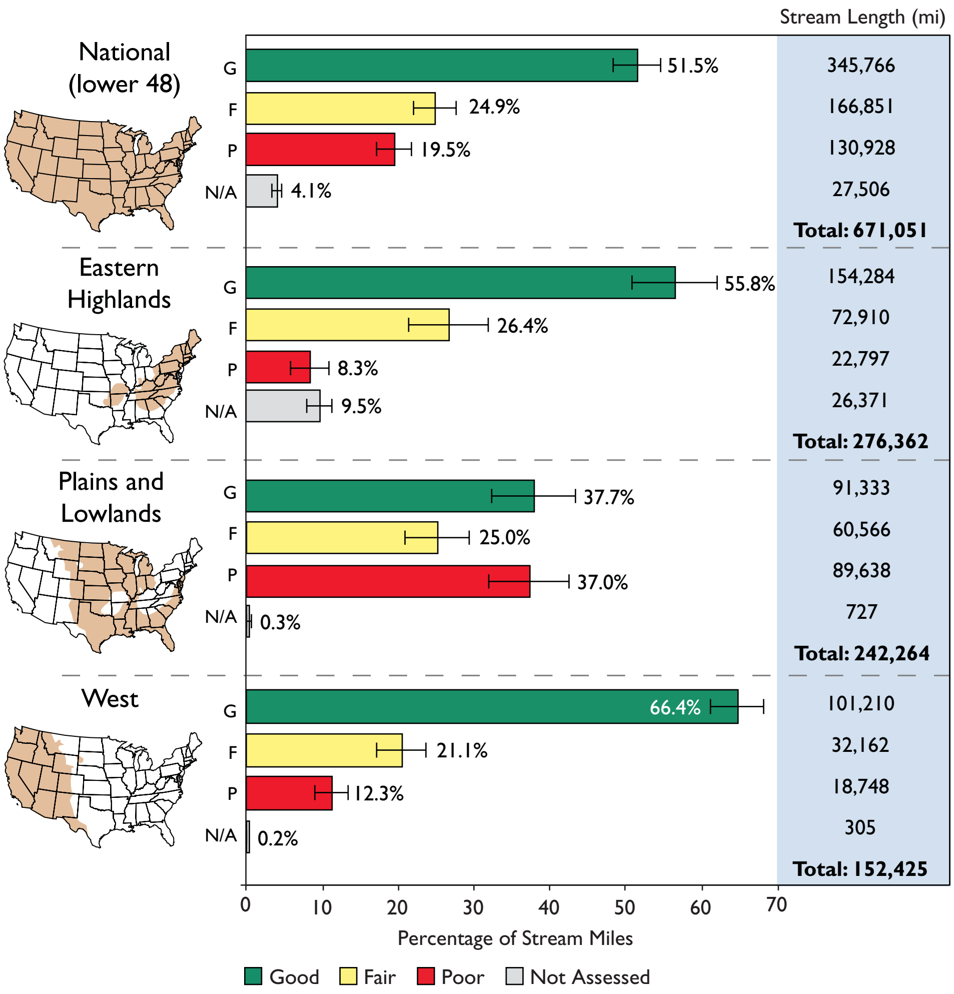


Figure 20. In-stream fish habitat in U.S. streams (U.S. EPA/WSA). This indicator sums the amount of in-stream habitat that field crews found in streams. Habitat consisted of undercut banks, boulders, large pieces of wood, and brush. Thresholds are based on conditions at regional reference sites.

watershed. Intact riparian areas can help reduce nutrient and sediment runoff from the surrounding landscape, prevent streambank erosion, provide shade to reduce water temperature, and provide leaf litter and large wood to serve as food and habitat for stream organisms. The presence of large, mature canopy trees in the riparian corridor indicates riparian longevity; the presence of smaller woody vegetation typically indicates that riparian vegetation is reproducing and suggests the potential for future sustainability of the riparian corridor. The WSA uses a measure of riparian vegetative cover that sums the amount of woody cover provided by three layers of riparian vegetation: the ground layer, woody shrubs, and canopy trees.

Findings for Riparian Vegetative Cover

Nineteen percent of the nation's stream length (129,748 miles) is in poor condition due to severely simplified riparian vegetation, 28% of stream length (190,034 miles) is in fair condition, and almost 48% (319,548 miles) is in good condition relative to least-disturbed reference condition in each of the nine WSA ecoregions (Figure 21). The West (12%, or 18,596 miles) and Eastern Highlands (18%, or 48,640 miles)

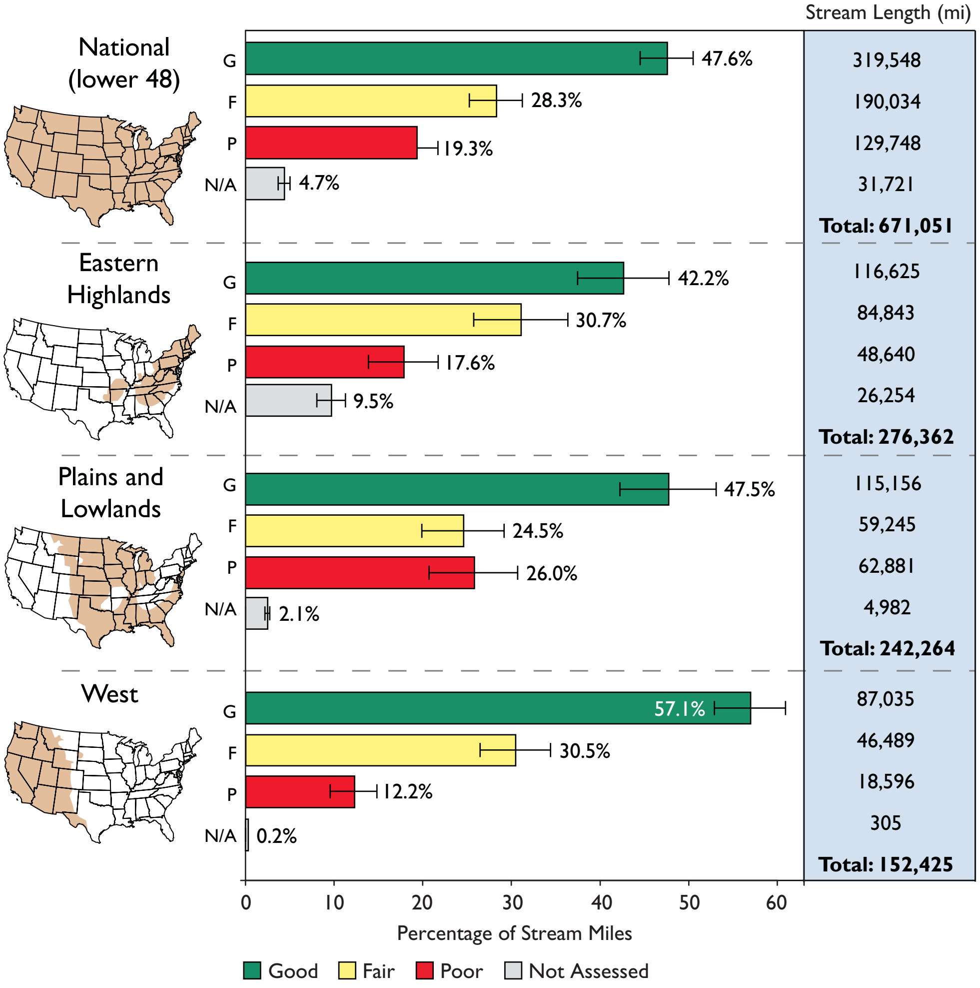
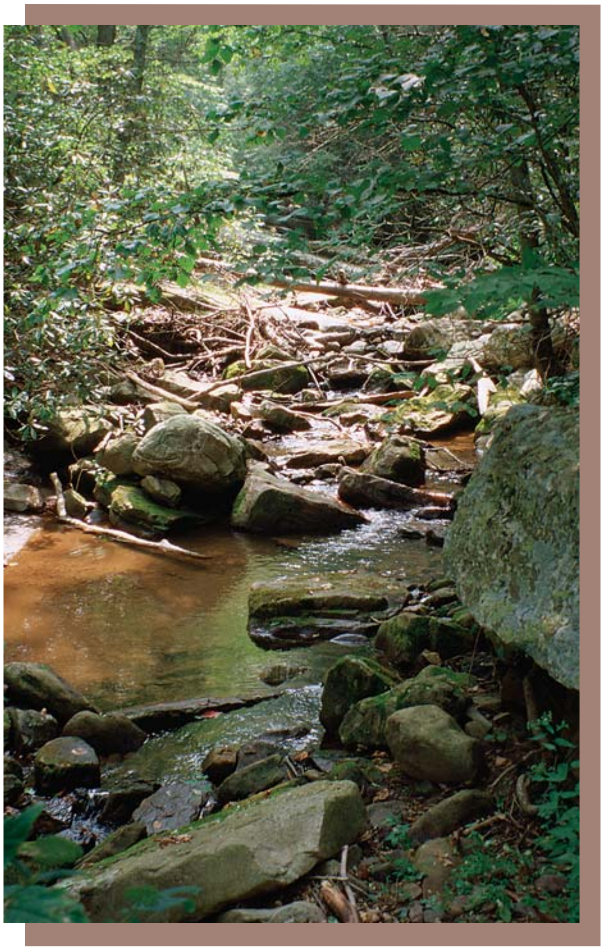


Figure 21. Riparian vegetative cover in U.S. streams (U.S. EPA/WSA). This indicator sums the amount of woody cover provided by three layers of riparian vegetation: the ground layer, woody shrubs, and canopy trees. Thresholds are based on conditions at regional reference sites.

regions have similar proportions of stream length with riparian vegetation in poor condition, though this equates to a greater number of stream miles in the Eastern Highlands region, where water is more abundant. In the Plains and Lowlands region, a larger proportion of stream length (26%, or 62,881 miles) has riparian vegetation in poor condition.



The most diverse fish and macroinvertebrate assemblages are found in streams and rivers that have complex forms of habitat, such as boulders, undercut banks, tree roots, and large wood within the stream banks (Photo courtesy of Michael L. Smith, FWS).

Riparian Disturbance

The vulnerability of the stream network to potentially harmful human activities increases with the proximity of those activities to the streams. The WSA uses a direct measure of riparian human disturbance that tallies 11 specific forms of human activities and disturbances along the stream reach and their proximity to a stream in 22 riparian plots along the stream. For example, streams scored medium if one type of human influence was noted in at least one-third of the plots, and streams scored high if one or more types of disturbance were observed in the stream or on its banks at all of the plots.

Findings for Riparian Disturbance

Twenty-six percent of the nation's stream length (171,118 miles) has high levels of human influence along the riparian zone that fringes stream banks, and 24% of stream length (158,368 miles) has relatively low levels of disturbance (Figure 22). The Eastern Highlands region has the greatest proportion of stream length with high riparian disturbance (29%, or 79,591 miles), followed by the Plains and Lowlands (26%, or 62,504 miles) and the West (19%, or 29,570 miles). One of the striking findings of the WSA is the widespread distribution of intermediate levels of riparian disturbance; 47% of the nation's stream length (314,052 miles) has intermediate levels of riparian disturbance when compared to reference condition, and similar percentages are found in each of the three major regions.

It is worth noting that for the nation and the three regions, the amount of stream length with good riparian vegetative cover was significantly greater than the amount of stream length with low levels of human disturbance in the riparian zone. This finding warrants

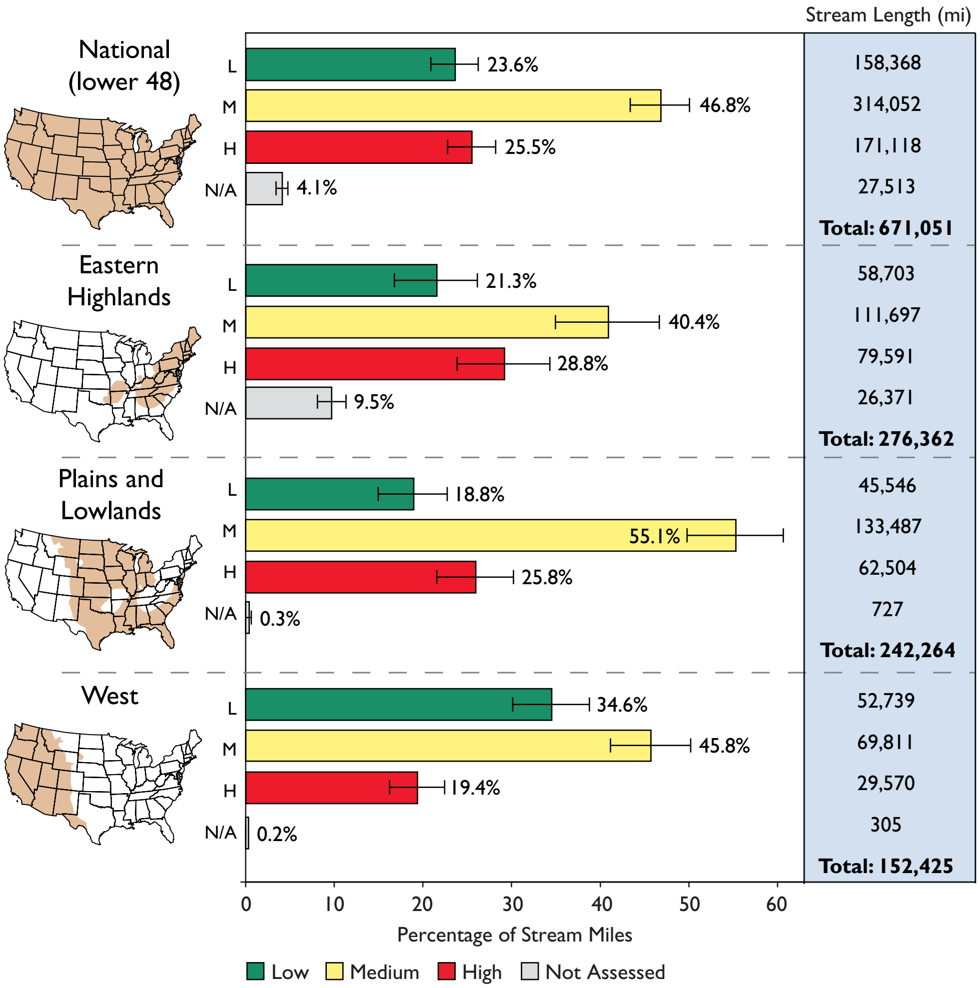


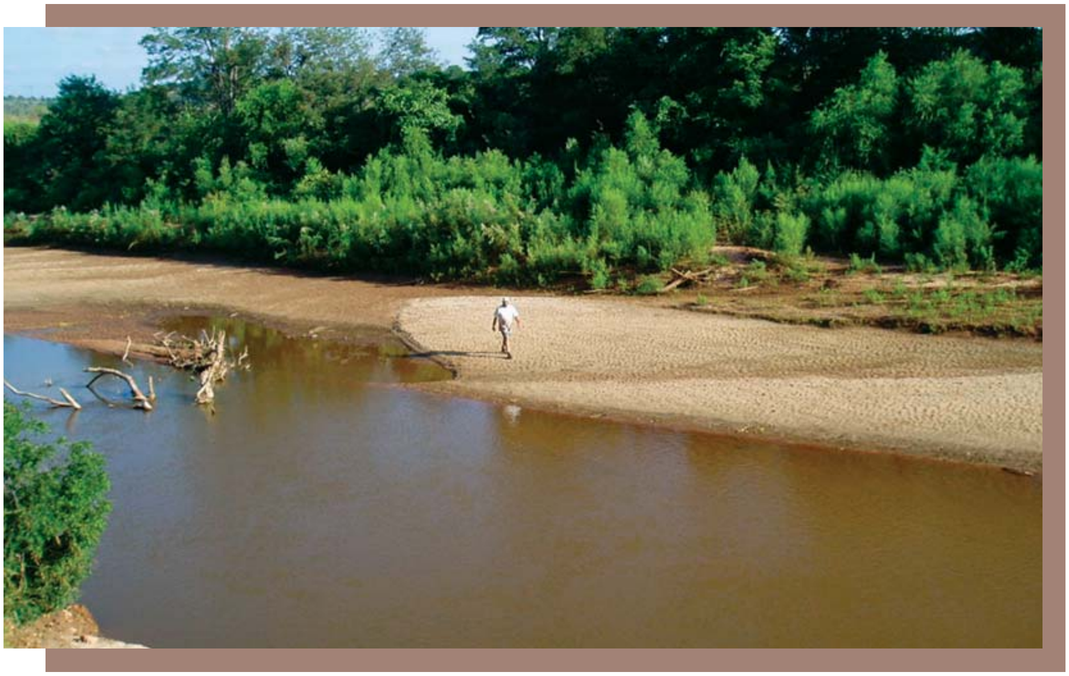
Figure 22. Riparian disturbance in U.S. streams (U.S. EPA/WSA). This indicator is based on field observations of 11 different types of human influence (e.g., dams, pavement, pasture) and their proximity to a stream in 22 riparian plots along the stream.

additional investigation, but suggests that land managers and property owners are protecting and maintaining healthy riparian vegetation buffers, even along streams where disturbance from roads, agriculture, and grazing is widespread.

Biological Stressors

Although most of the factors identified as stressors to streams and rivers are either chemical or physical, there are biological factors that also create stress in wadeable streams. Biological assemblages can be stressed by the presence of non-native species that can either prey on, or compete with, native species. In many cases, non-native species have been intentionally introduced to a waterbody; for example, brown trout and brook trout are common inhabitants of streams in the higher elevation areas of the West, where they have been stocked as game fish.

When non-native species become established in either vertebrate or invertebrate assemblages, their presence conflicts with the definition of biological



Little Washita River, OK, in the Plains and Lowlands region (Photo courtesy of Monty Porter).

integrity that the CWA is designed to protect (i.e., "having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region"). Therefore, to the extent that non-native species compete with and potentially exclude native species, they might be considered a threat to biological integrity. These indicators were not included in the WSA, but may be included in future assessments.

Ranking of Stressors

A prerequisite to making policy and management decisions is to understand the relative magnitude or importance of potential stressors. It is important to consider both the prevalence of each stressor (i.e., what is its extent, in miles of stream, and how does it compare to other stressors) and the severity of each stressor (i.e., how much influence does it have on biological condition, and is its influence greater or smaller than the influence of other stressors). The WSA presents separate rankings of the extent and the relative severity of stressors to the nation's flowing waters. Ideally, both of these factors (extent and effect) should be combined into a single measure of relative importance. EPA is pursuing methodologies for combining the two rankings and will present them in future assessments.

Extent of Stressors

Figure 23 shows the WSA stressors ranked according to the proportion of stream length that is in poor condition. Results are presented for the nation (top panel) and for each major region, with the stressors ordered (in all panels) according to their relative extent nationwide.

Figure 23 reveals that excess total nitrogen is the most pervasive stressor for the nation, although it is not the most pervasive in each region. Approximately 32% of the nation's stream length (213,394 miles) shows high concentrations of nitrogen compared to reference conditions. In the Plains and Lowlands region, nitrogen is at high concentrations in 27% of stream length (65,715 miles), whereas this proportion climbs to 42% (117,285 miles) in the Eastern Highlands region. Even in the West, where levels of disturbance are generally lower than the other major regions, excess total nitrogen is found in 21% of the stream length (31,247 miles). Phosphorus exhibits comparable patterns to nitrogen and is the second most-pervasive stressor for the nation's stream length.

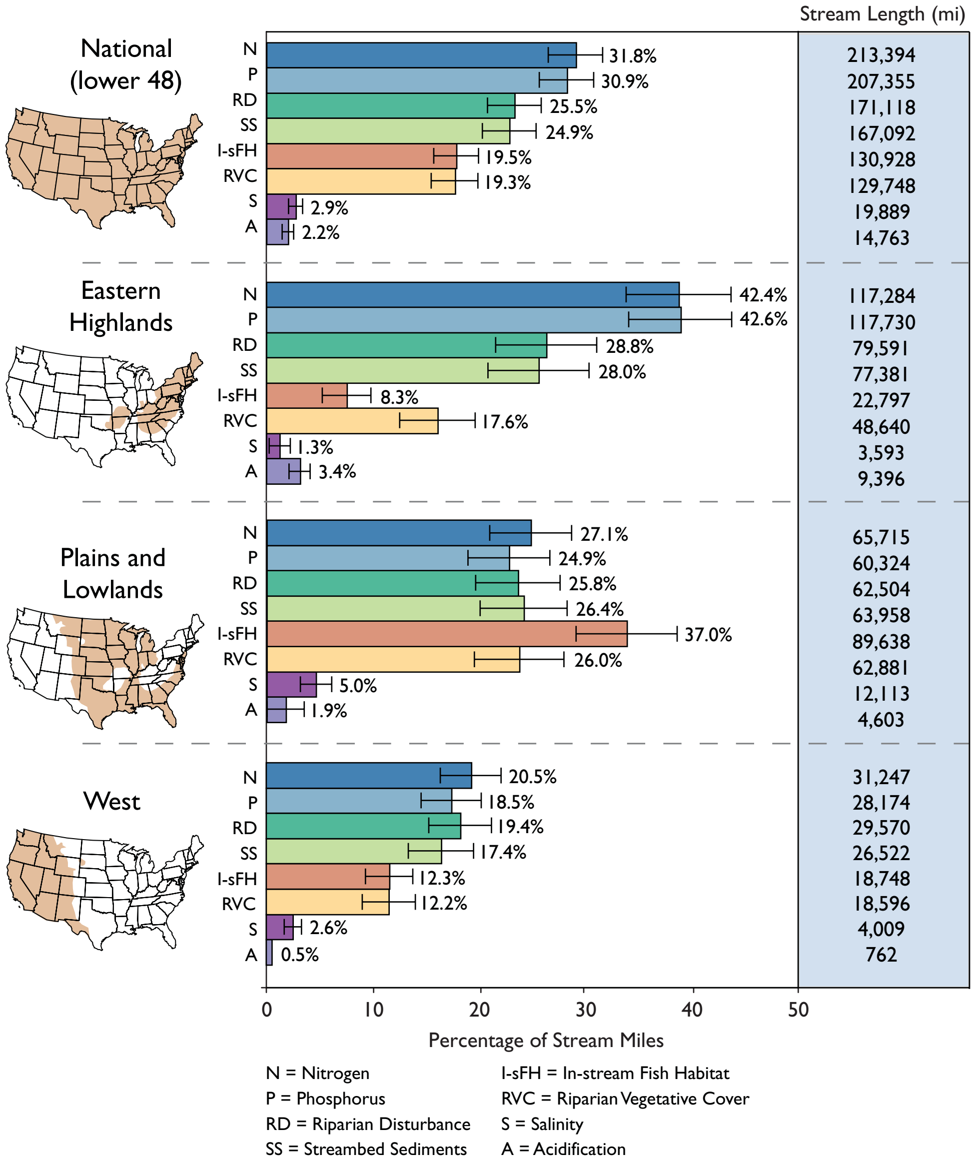


Figure 23. Extent of stressors (i.e., proportion of stream length ranked in poorest category for each stressor) (U.S. EPA/WSA).

The least-common stressors for the nation's stream length are salinity and acidification. Only 3% (19,889 miles) and 2% (14,763 miles), respectively, of the nation's stream length is in poor condition for salinity and acidification levels. Although these stressors are not present in large portions of the nation's streams, they can have a significant impact where they do occur.

The extent of stressors measured in the WSA varies across the three major regions. In the Plains and Lowlands region, the stressor rated poor for the greatest proportion of stream length (37%, or 89,638 miles) is loss of in-stream fish habitat. In the Eastern Highlands region, high total nitrogen and total phosphorus concentrations were found in more than 42% of the stream length (117,285 and 117,730 miles, respectively). In the West, no stressor is found to affect more than 21% of stream length (31,247 miles), although nitrogen, phosphorus, and riparian disturbance are the most widespread stressors in this region as well.

Relative Risk of Stressors to Biological Condition

This report borrows the concept of relative risk from the medical field to address the question of severity of stressor effects. We have all heard that we run a greater risk of developing heart disease if we have high cholesterol levels. Often such results are presented in terms of a relative-risk ratio (e.g., the risk of developing heart disease is 4 times higher for a person with a total cholesterol level greater than 300 mg than for a person with a total cholesterol level of less than 150 mg).

The relative-risk values for aquatic stressors can be interpreted in the same way as the cholesterol example. For each of the key stressors, Figure 24 depicts how much more likely a stream is to have poor biological condition if stream length is in poor condition for a stressor or if high concentrations of a stressor are present than if the stream length is in good condition for a stressor or a stressor is found at low concentrations. Because different aspects of the macroinvertebrate assemblage (i.e., biological condition vs. taxa loss) are expected to be affected by different stressors, the WSA calculates relative risk separately for each of the two biological condition indicators (Macroinvertebrate Index and O/E Taxa Loss).

A relative-risk value of 1 indicates that there is no association between the stressor and the biological indicator, whereas values greater than 1 suggest that the stressor poses a greater relative risk to biological condition. The WSA also calculates confidence intervals (Figure 24) for each relative risk ratio. When the confidence interval extending above and below the ratio does not overlap the value of 1, the relative risk estimate is statistically significant.

The relative risks shown in Figure 24 provide an estimate of the severity of each stressor's effect on the macroinvertebrate community in streams. Almost all of the stressors evaluated for the WSA were associated with increased risk for macroinvertebrates. Evaluating relative risk provides insight on which stressors might be addressed to improve biological condition. Excess nitrogen, phosphorus, and streambed sediments stand out as having the most significant impacts on biological condition based on both the Macroinvertebrate Index and O/E Taxa Loss indicators. Findings show that streams with relatively high concentrations of nutrients or excess streambed sediments are two to four times more likely to have poor macroinvertebrate condition.

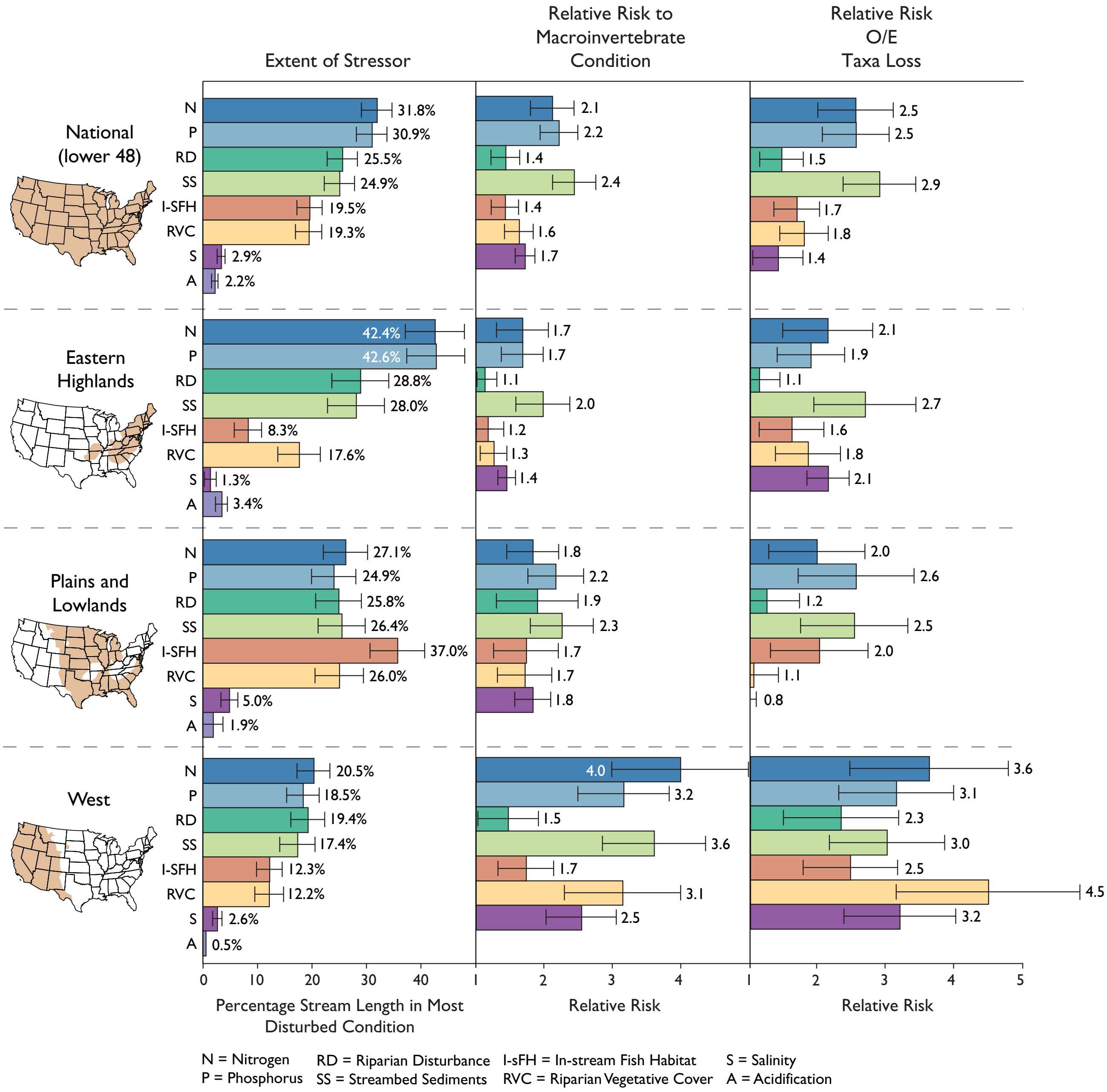


Figure 24. Extent of stressors and their relative risk to Macroinvertebrate Condition and O/E Taxa Loss (U.S. EPA/WSA). This figure shows the association between a stressor and biological condition and answers the question, "What is the increased likelihood of poor biological condition when stressor X is rated in poor condition?" It is important to note that this figure treats each stressor independently and does not account for the effects of combinations of stressors.

There are differences in relative risk from a geographic perspective. In general, the West exhibits a higher relative risk for the majority of stressors than the Eastern Highlands and the Plains and Lowlands regions. There are also differences associated with the different indicators of biological condition. The O/E Taxa Loss indicator has somewhat higher relative risk ratios for most of the stressors than the Macroinvertebrate Index. Additional analysis is needed to further explore these differences.

In this assessment of relative risk, it is impossible to separate completely the effects of the individual stressors that often occur together. For example, streams with high nitrogen concentrations often exhibit high phosphorus concentrations, and streams with high riparian disturbance often have sediments far in excess of expectations; however, the analysis presented in Figure 24 treats the stressors as if they operate independently.

Combining Extent and Relative Risk

The most comprehensive assessment of the ranking of stressors comes from evaluating both the extent (Figure 23) and relative risk (Figure 24) results. Stressors that pose the greatest overall risk to biological integrity will be those that are both widespread (i.e., rank high in terms of the extent of stream length in poor condition for a stressor in Figure 23) and whose effects are potentially severe (i.e., exhibit high relative risk ratios in Figure 24). The WSA facilitates this combined evaluation of stressor importance by including side-by-side comparisons of the extent of stressors and relative risk to macroinvertebrate condition in Figure 24.

An examination of nationwide results suggests some common patterns for key stressors and the two indicators of biological condition. Total nitrogen, total phosphorus, and excess streambed sediments are stressors posing the greatest relative risk nationally (relative risk greater than 2), and they also occur in 25–32% of the nation's stream length. This suggests that management decisions aimed at reducing excess sediment, nitrogen, and phosphorus loadings to streams could have a positive impact on macroinvertebrate biological integrity and prevent further taxa loss across the country.

High salinity in the West is strongly associated with a poor Macroinvertebrate Index score (relative risk = 2.5) and O/E Taxa Loss score (relative risk > 3.1 or = 3.2); however, the rarity of this occurrence (salinity affects only 3% of stream length in the West region) suggests that excess salinity is a local issue requiring a locally targeted management approach rather than a national or regional effort.

Relative risks for all stressors in the West region are consistently larger than for the nation overall or for the other two regions, yet the extent of streams in poor condition for these stressors is consistently lower in the West. This suggests that although the stressors are not widespread in the West, the region's streams are particularly sensitive to a variety of disturbances.

Chapter 3

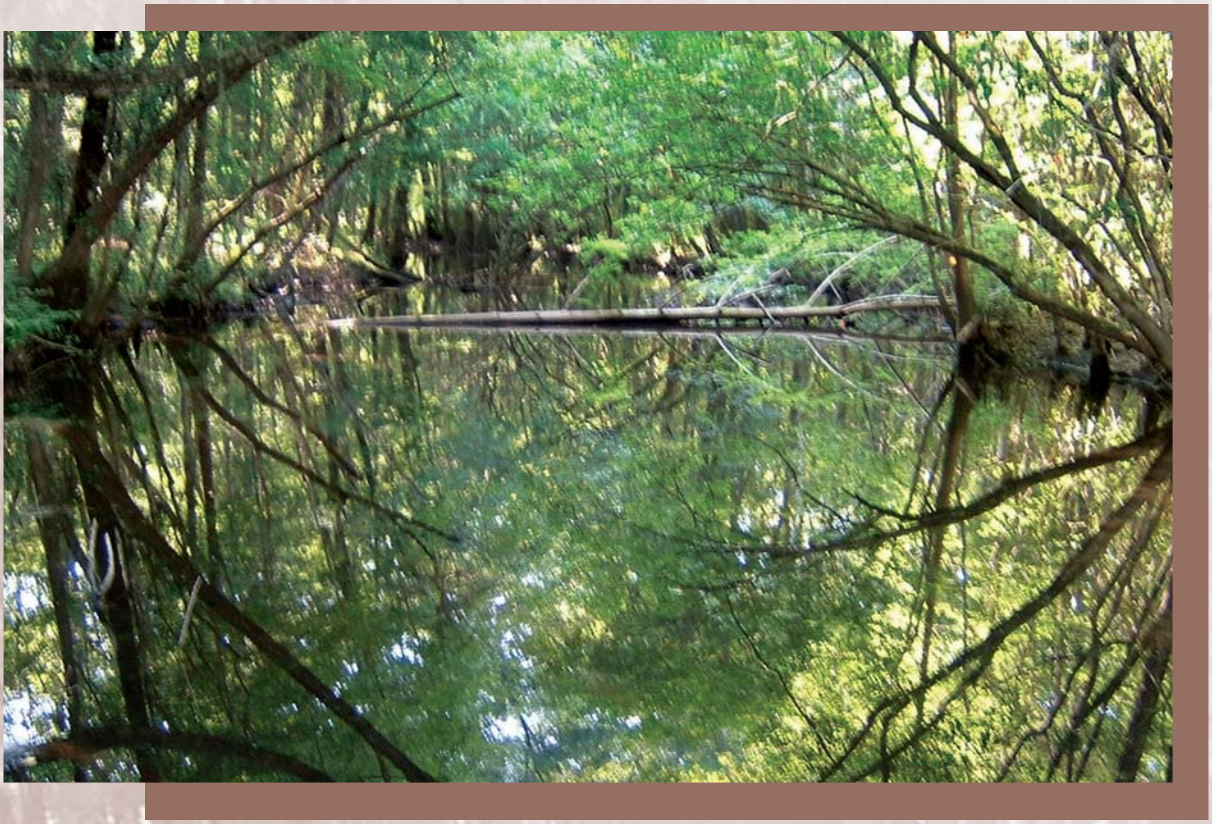


Photo courtesy of the Georgia Department of Natural Resources

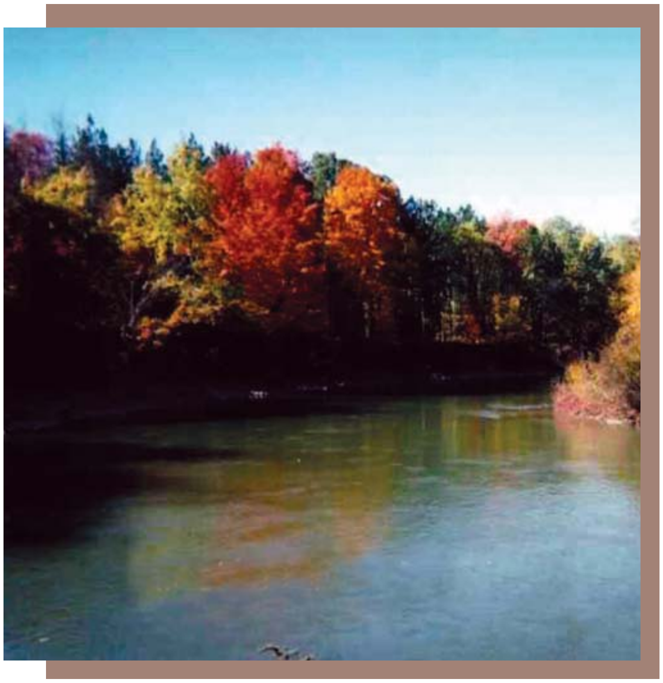
Wadeable Streams Assessment Ecoregion Results

Wadeable Streams Assessment Ecoregion Results

The WSA is designed to report on three geographic scales: national, regional, and ecoregional. Chapter 2 presented the national- and regional-scale results, and this chapter will focus on the results for the nine WSA ecoregions.

Ecoregions are areas that contain similar environmental characteristics, such as climate, vegetation, soil type, and geology. EPA has defined ecoregions at various scales, ranging from coarse (Level I) ecoregions at the continental scale to fine (Levels III and IV) ecoregions that divide states into smaller ecosystem units. Ecoregions are designed to be used in environmental assessments, for setting water quality and biological criteria, and to set management goals for non-point source pollution.

The nine WSA ecoregions are aggregations of the Level III ecoregions delineated by EPA for the conterminous United States. This chapter provides background information on physical setting, biological setting, and human influence for each of the WSA ecoregions and describes WSA results for the wadeable stream length throughout each ecoregion. The WSA results may not be extrapolated to an individual state or stream within the ecoregion because the study design was not intended to characterize stream conditions at these finer scales. Note that a number of states implement randomized designs at the state scale to characterize water quality throughout their state, but these characterizations are not described in this WSA report.



Manistee River, MI, in the Upper Midwest ecoregion (Photo courtesy of the Great Lakes Environmental Center).

The nine ecoregions encompass a variety of habitats and land uses, and the least-disturbed reference sites used to set benchmarks for good, fair, and poor condition reflect that variability. For some ecoregions, the variability among reference sites is very small, while it is larger in others. During a series of WSA workshops held around the country, professional biologists examined the variability of reference sites and implications to the benchmarks used to characterize an ecoregion and to compare stream condition across ecoregions. These benchmarks or thresholds were adjusted for those ecoregions where there was a disturbance signal associated with the variability among reference sites. Additional details on the development of benchmarks or thresholds for each of the indicators can be found in the data analysis method available in Chapter 1 and on the EPA Web site at http://www.epa.gov/owow/streamsurvey.

This report includes brief descriptions of the WSA ecoregions. It should be noted that there are many specific and unique features within each ecoregion that are not fully captured in these brief descriptions (see the References section at the end of this report for more information). The nine ecoregions displayed in Figure 25 and defined in this text are the following:

- Northern Appalachians
- Southern Appalachians
- Coastal Plains
- Upper Midwest
- Temperate Plains
- Southern Plains
- Northern Plains
- Western Mountains
- Xeric.

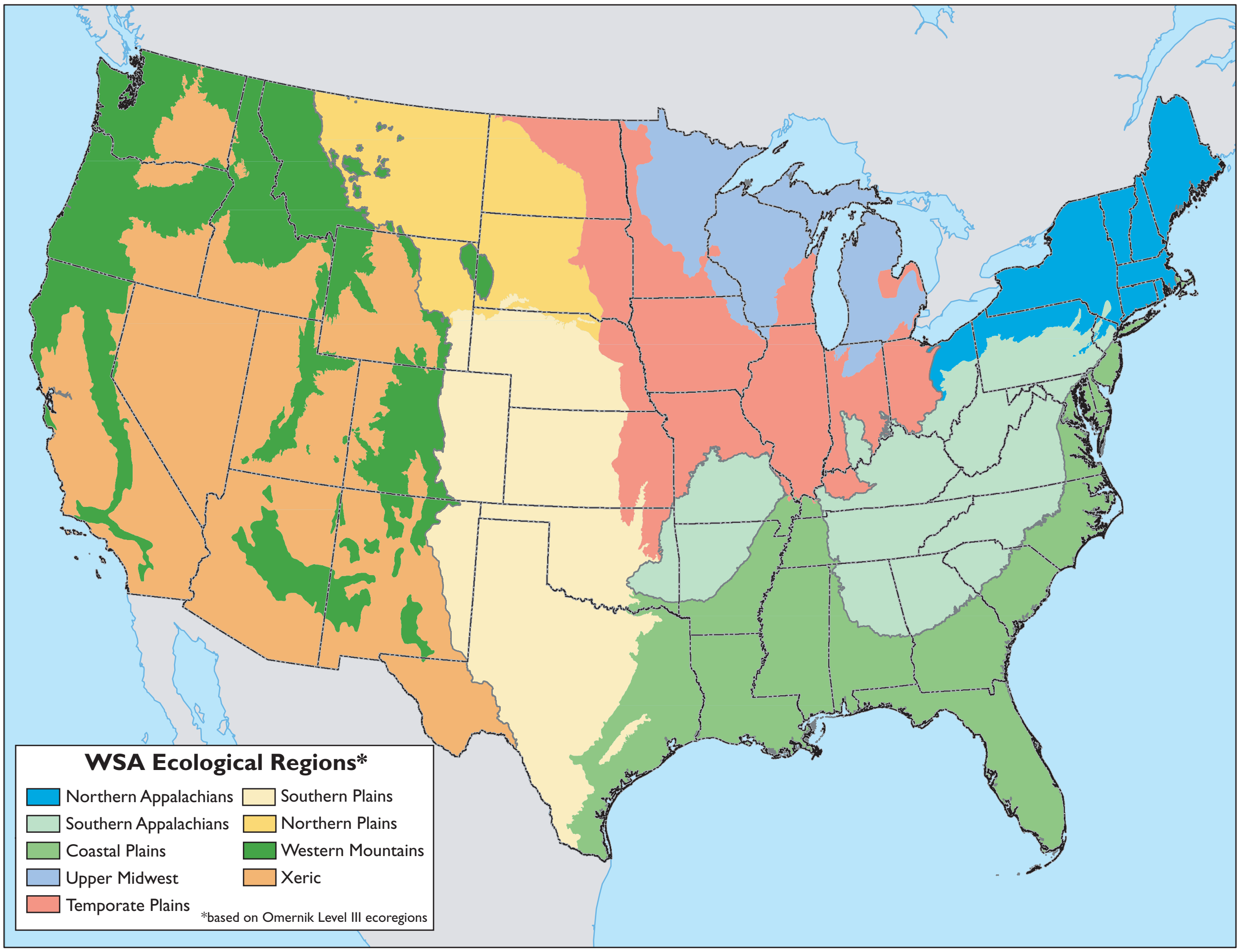


Figure 25. Ecoregions surveyed for the WSA (U.S. EPA/WSA).

Northern Appalachians Ecoregion

Physical Setting

The Northern Appalachians ecoregion covers all of the New England states, most of New York, the northern half of Pennsylvania, and northeastern Ohio. This ecoregion encompasses New York's Adirondack and Catskill mountains and Pennsylvania's mid-northern tier, including the Allegheny National Forest. Major river systems for the Northern Appalachians ecoregion are the St. Lawrence, Allegheny, Penobscot, Connecticut, and Hudson rivers, and major waterbodies include Lake Ontario, Lake Erie, New York's Finger Lakes, and Lake Champlain. The total stream length represented in the WSA for the Northern Appalachians ecoregion is 97,913 wadeable stream miles.

The topography of this ecoregion is generally hilly, with some intermixed plains and old mountain ranges. River channels in the glaciated uplands of the northern parts of this ecoregion have steep profiles and rocky beds, and flow over glacial sediments. The climate is cold to temperate, with mean annual temperatures ranging from 39 to 48 °F. Annual precipitation totals range from 35 to 60 inches. The land area of Northern Appalachians ecoregion comprises some 139,424 mi^2 (4.6% of the United States), with about 4,722 mi^2 (3.4%) of land under federal ownership. Based on satellite images from the 1992 National Land Cover Dataset (NLCD), the distribution of land cover in this ecoregion is 69% forested and 17% planted/cultivated, with the remaining 14% of the ecoregion comprised of other types of land cover.

Cedar Stream, NH, in the Northern Appalachians ecoregion (Photo courtesy of Colin Hill, Tetra Tech, Inc.).

Biological Setting

Contemporary fish stocks are lower than at the time of European contact, but the coastal rivers of the Northern Appalachians ecoregion still have a wide variety of anadromous fish, including shad, alewife, salmon, and sturgeon.

Human Influence

Early European settlers in 17th-century New England removed beaver dams, allowing floods to pass more quickly, thereby flushing sediment and decreasing the diversity and availability of riparian habitat. Forests were cleared to introduce crops and pasture for grazing animals, and these efforts caused the erosion of sediments, increased nutrients, and reduced riparian habitat. Roughly 96% of the original virgin forests of the eastern and central states were gone by the 1920s.

Smaller tributaries in this ecoregion were often disrupted through splash damming — a 19th century practice of creating dam ponds for collecting timber and then exploding the dams to move timber downstream with the resulting torrent of flood waters. These waters carried flushed sediment and wood downstream, and these materials scoured many channels to bedrock. Streams that were not splash dammed currently have tens to hundreds of times more naturally occurring woody debris and deeper pools. During the 18th and early 19th centuries, streams with once-abundant runs of anadromous fish declined due to stream sedimentation, clogging from sawmill discharges, and the effects of dams. Increased human and animal waste from agricultural communities changed stream nutrient chemistry. When agriculture moved west and much of the ecoregion's eastern farmland converted back into woodlands, sediment yields declined in some areas.

Today, major manufacturing, chemical, steel, and power production (e.g., coal, nuclear, oil) occur in the large metropolitan areas found around New York City and the states of Connecticut and Massachusetts. Many toxic substances, including petroleum products, organochlorines, polychlorinated biphenyls (PCBs), and heavy metals, along with increased nutrients such as nitrates and phosphates, are the legacy of industrial development. There are currently 215 active, 6 proposed, and 45 former EPA Superfund National Priority List sites in the Northern Appalachian ecoregion.

It is also common for treated wastewater effluent to account for much of the stream flow downstream from major urban areas in this ecoregion. Treated wastewater can be a major source of nitrate, ammonia, phosphorus, heavy metals, volatile organic chemicals (VOCs), PCBs, and other toxic compounds.

This ecoregion supports forestry; mining; fishing; wood processing of pulp, paper, and board; tourism; and agricultural activities, such as dairy cattle farming, potato production, poultry farming, and timber harvesting.

The approximate population within the Northern Appalachians ecoregion is 40,550,000, representing approximately 14% of the total population of the United States.

Summary of WSA Findings

A total of 85 WSA sites were sampled during the summer of 2004 to characterize the condition of wadeable streams in the Northern Appalachians ecoregion. An overview of the WSA survey results for this ecoregion is shown in Figure 26. These results may not be extrapolated to accurately assess the ecological condition of an individual state or stream within the ecoregion because the study design was not intended to characterize stream conditions at these finer scales.

It should be noted that about 27% of wadeable stream length in the Northern Appalachians ecoregion was not assessed because small, 1st-order streams in New England were not included in the sample frame. These streams were excluded from the WSA due to a decision to match an earlier New England random design. The numbers cited below apply to the 73% of wadeable stream length that was assessed in the Northern Appalachians ecoregion.

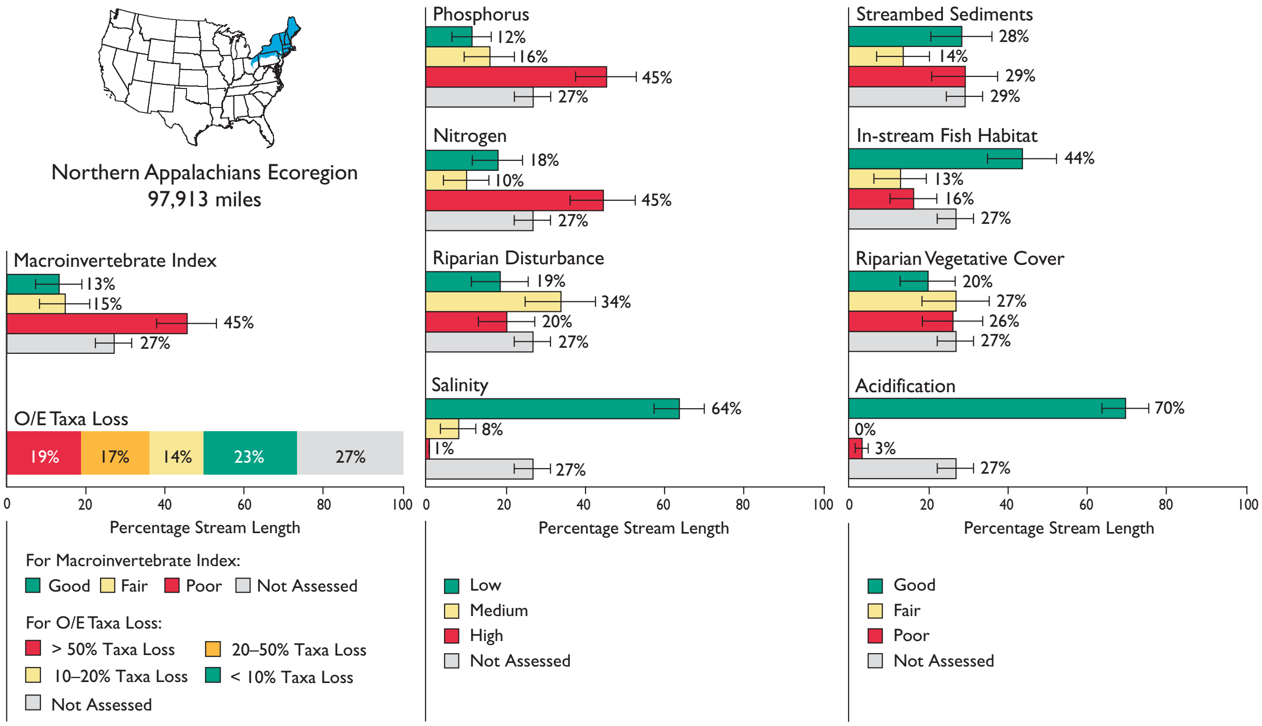


Figure 26. WSA survey results for the Northern Appalachians ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Northern Appalachians ecoregion said that many least-disturbed reference sites in this ecoregion are nearly undisturbed streams, with sparse human population in the immediate watershed; therefore, the reference condition for the ecoregion is of very high quality.

Biological Condition

- The findings of the Macroinvertebrate Index show that 45% of stream length in the Northern Appalachians ecoregion is in poor condition, 15% is in intermediate or fair condition, and 13% is in good condition when compared to least-disturbed reference condition. As noted above, 1st-order streams, which are generally considered to be of high quality in this ecoregion, were not included in the WSA.
- The O/E Taxa Loss results show that 50% of stream length in the Northern Appalachians ecoregion has lost 10% or more of the macroinvertebrate taxa expected to occur, and 19% has lost more than 50% of taxa. These results indicate that 23% of stream length has retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

Indicators of Stress

Leading indicators of stress in the Northern Appalachians ecoregion include total phosphorus, total nitrogen, streambed sediments, and riparian vegetative cover.

- Approximately 45% of stream length in the Northern Appalachians ecoregion has high phosphorus concentrations, 16% has medium phosphorus concentrations, and 12% has low phosphorus concentrations based on least-disturbed reference condition.
- Similarly, approximately 45% of the ecoregion's stream length has high nitrogen concentrations, 10% has medium nitrogen concentrations, and 18% has low nitrogen concentrations based on least-disturbed reference condition.
- Riparian disturbance, or evidence of human influence in the riparian zone, is at high levels in 20% of stream length, at medium levels in 34% of stream length, and at low levels in 19% of stream length.
- Salinity is found at high levels in 1% of stream length, at medium levels in 8% of stream length, and at low levels in 64% of stream length.
- Streambed sediments are rated poor in 29% of stream length in the Northern Appalachians ecoregion, fair in 14%, and good in 28%.
- In-stream fish habitat is in poor condition in 16% of stream length, fair in 13% of stream length, and good in 44%.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 26% of stream length, fair condition for 27% of stream length, and good condition for 20% of stream length.
- Acidification, which is primarily associated with acid rain in this ecoregion, is rated poor in 3% of stream length.

Stream channels in the glaciated uplands of the Northern Appalachians are characterized by steep profiles and rocky beds (Photo courtesy of Lauren Holbrook, IAN Image Library).

Southern Appalachians Ecoregion

Physical Setting

The Southern Appalachians ecoregion stretches over 10 states, from northeastern Alabama to central Pennsylvania, and includes the interior highlands of the Ozark Plateau and the Ouachita Mountains in Arkansas, Missouri, and Oklahoma.

The land area of the Southern Appalachians ecoregion covers about 321,900 mi^2 (10.7% of the United States), with about 42,210 mi^2 (13.1%) of land under federal ownership. Many significant public lands, such as the Great Smoky Mountains National Park, the George Washington and Monongahela national forests, and the Shenandoah National Park, reside within this ecoregion. The topography is mostly hills and low mountains, with some wide valleys and irregular plains. Piedmont areas are included within the Southern Appalachians ecoregion.

Rivers in this ecoregion flow mostly over bedrock and other resistant rock types, with steep channels and short meander lengths. Major rivers such as the Susquehanna, James, and Potomac, along with feeders into the Ohio and Mississippi river systems, such as the Greenbrier River in West Virginia, originate in this ecoregion. The total stream length represented in the WSA for the Southern Appalachians ecoregion is 178,449 wadeable stream miles.

This ecoregion's climate is considered temperate wet, and annual precipitation totals average 40 to 80 inches. Mean annual temperature ranges from 55 to 65 °F. Based on satellite images in the 1992 NLCD, the distribution of land cover in this ecoregion is 68% forested and 25% planted/cultivated, with the remaining 7% in other types of land cover.

Biological Setting

The Southern Appalachians ecoregion has some of the greatest aquatic animal diversity of any area in North America, especially for species

Young Womans Creek, PA, in the Southern Appalachians ecoregion (Photo courtesy of the Great Lakes Environmental Center).

of amphibians, fishes, mollusks, aquatic insects, and crayfishes. Salamanders, plants, and fungi reach their highest North American diversity in the Southern Appalachians ecoregion; however, some 18% of animal and plant species in the ecoregion are threatened or endangered.

Some areas in the Southern Appalachians ecoregion are among the least-impacted pre-settlement vegetative cover in the United States, such as the spruce-fir forests in the southern part of the ecoregion. The Great Smoky Mountains National Park and other national forests continue to protect exceptional stands of old-growth forest riparian ecosystems.

Human Influence

The effects of habitat fragmentation, urbanization, agriculture, channelization, diversion, and impoundments on river systems have altered a large amount of stream length in the Southern Appalachians ecoregion. Placer mining, which disrupts streambeds and increases a stream's ability to transport fine sediments that influence habitat and water quality downstream, began in the Appalachians in the 1820s. In addition, some 800 mi^2 were surface mined in the Appalachian Highlands between 1930 and 1971, leading to the acidification of streams and reduction of aquatic diversity. Placer mining and surface mining operations have introduced many toxic contaminants to river systems in the Southern Appalachians ecoregion, including arsenic, antimony, copper, chromium, cadmium, nickel, lead, selenium, silver, and zinc. There are 224 active, 5 proposed, and 46 deleted EPA Superfund National Priority List sites in this ecoregion.

Economic activities in the Southern Appalachians ecoregion include forestry, coal mining, and some local agriculture and tourism industries. Petroleum and natural gas extraction are prevalent along the coal belt, and the ecoregion supports coal, bauxite, zinc, copper, and chromium mining activities. Utility industries include hydro-power in the Tennessee Valley and numerous coal-fired plants throughout the ecoregion. Significant agricultural activities are alfalfa production in Pennsylvania, with apple and cattle production occurring throughout the ecoregion. Wood processing and pulp, paper, and board production are also prevalent.

Approximately 50,208,000 people live in the Southern Appalachians ecoregion, representing approximately 17% of the total population of the United States.

Summary of WSA Findings

A total of 184 random sites were sampled during the summer of 2004 to characterize the condition of wadeable streams in the Southern Appalachians ecoregion. An overview of the WSA survey results for the ecoregion is shown in Figure 27. These results may not be extrapolated to an individual state or stream within the ecoregion because the study design was not intended to characterize stream conditions at these finer scales.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Southern Appalachians ecoregion said that the least-disturbed reference streams in the ecoregion represent varying degrees of human influence. Although some reference streams are in remote areas, others are intricately linked with road systems in narrow floodplains.

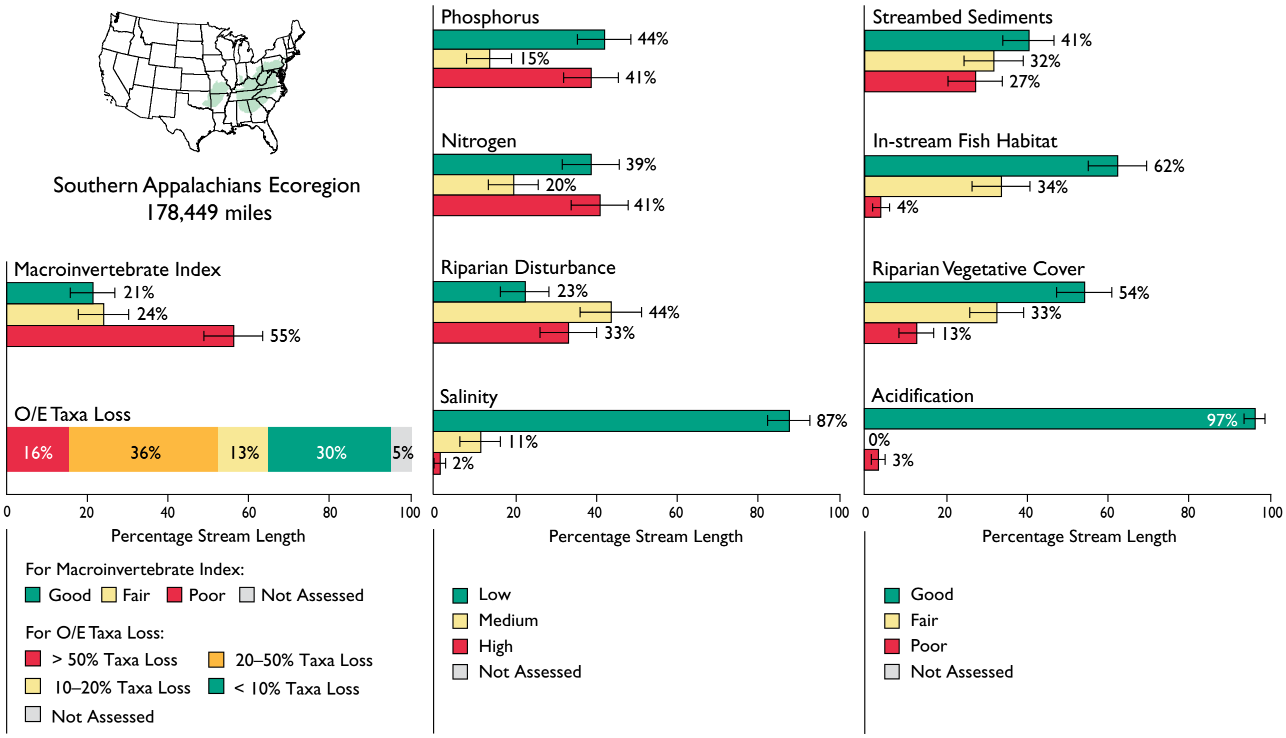


Figure 27. WSA survey results for the Southern Appalachians ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

Biological Condition

- The Macroinvertebrate Index shows that 55% of stream length in the Southern Appalachians ecoregion is in poor condition, 24% is in fair or intermediate condition, and 21% is in good condition compared to least-disturbed reference condition.
- The O/E Taxa Loss results show that 65% of stream length in the Southern Appalachians ecoregion has lost 10% or more of the macroinvertebrate taxa that are expected to occur, and 16% has lost more than 50% of taxa. These results also indicate that 30% of stream length has retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

Indicators of Stress

Leading indicators of stress in the Southern Appalachians ecoregion include total nitrogen, total phosphorus, riparian disturbance, and streambed sediments.

- Forty-one percent of stream length in the Southern Appalachians ecoregion has high phosphorus concentrations, 15% has medium phosphorus concentrations, and 44% has low phosphorus concentrations based on least-disturbed reference condition.
- Nitrogen concentrations in the ecoregion are high in 41% of stream length, medium in 20% of stream length, and low in 39% of stream length based on least-disturbed reference condition.

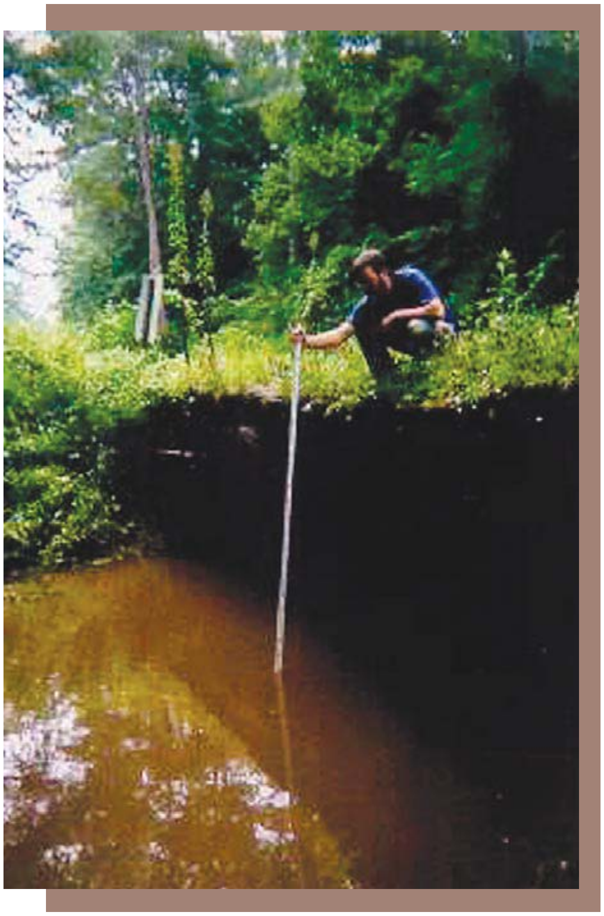
- Riparian disturbance, or evidence of human influence in the riparian zone, is at high levels in 33% of stream length, at medium levels in 44% of stream length, and at low levels in 23% of stream length.
- Salinity is found at high levels in only 2% of stream length, at medium levels in 11% of stream length, and at low levels in 87% of stream length.
- Streambed sediments are rated poor in 27% of stream length in the Southern Appalachians ecoregion, fair in 32%, and good in 41%.
- In-stream fish habitat is in poor condition in 4% of stream length, fair in 34% of stream length, and good in 62%.
- Vegetative cover in the riparian zone along Southern Appalachian stream banks is in poor condition in 13% of stream length, fair in 33% of stream length, and good in 54% of stream length.
- Acidification, which is primarily associated with acidic deposition and acid mine drainage in this ecoregion, is rated poor in 3% of stream length.

Coastal Plains Ecoregion

Physical Setting

The Coastal Plains ecoregion covers the Mississippi Delta and Gulf Coast, north along the Mississippi River to the Ohio River, all of Florida and eastern Texas, and the Atlantic seaboard from Florida to New Jersey. The total land area of this ecoregion is about 395,000 mi^2 (13.2% of the United States), with 25,890 mi^2 (6.6%) of land under federal ownership. River systems lying within or intersecting the Coastal Plains ecoregion are the Mississippi, Suwannee, Savannah, Roanoke, Potomac, Delaware, Susquehanna, James, Sabine, Brazos, and Guadalupe rivers.

Rivers in the Coastal Plains meander broadly across flat plains created by thousands of years of river deposition and form complex wetland topographies with levees, backswamps, and oxbow lakes. Rivers typically drain densely vegetated catchment areas, while well-developed soils and less intensive rains and subsurface flows keep suspended sediment levels in the rivers relatively low. The Mississippi River carries large loads of sediments from dry lands in the central and western portion of the drainage. The total stream length represented in the WSA for the Coastal Plains ecoregion is 72,130 wadeable stream miles.



Sandy Creek, LA, in the Coastal Plains ecoregion (Photo courtesy of the Great Lakes Environmental Center).

The Coastal Plains ecoregion contains about one-third of all remaining U.S. wetlands, more than half of U.S. forested wetlands, and the largest aggregate area of U.S. riparian habitat. The topography of the area is mostly flat plains, barrier islands, numerous wetlands, and about 50 important estuarine systems that lie along the coastal margins. The climate of this ecoregion is considered temperate wet to subtropical in the south, with average annual temperatures ranging from 50 to 80 °F and annual precipitation ranging from 30 to 79 inches. Based on satellite images in the 1992 NLCD, the distribution of land cover in this ecoregion is 39% forested, 30% planted/cultivated, and 16% wetlands, with the remaining 15% of the ecoregion comprised of other types of land cover.

Biological Setting

River habitats in the Coastal Plains ecoregion have tremendous species richness and the highest number of endemic species of aquatic organisms in North America. Abundant fish, crayfish, mollusk, aquatic insect, and other species include such unique species as paddlefish, catostomid suckers, American alligator, and giant aquatic salamanders; however, it is estimated that some 18% of the aquatic species in this ecoregion are threatened or endangered. The Coastal Plains ecoregion includes the Florida Everglades, which contains temperate and tropical plant communities and a rich variety of bird and wildlife species; however, because it is a unique aquatic ecosystem, the Everglades is not represented in the WSA.

Human Influence

Historically, the Coastal Plains ecoregion had extensive bottomlands that flooded for several months; these areas are now widely channelized and confined by levees. Damming, impounding, and channelization in almost all major rivers have altered the rate and timing of water flow, as well as the productivity of riparian habitats. Pollution from acid mine drainage, urban runoff, air pollution, sedimentation, and recreation, as well as the introduction of non-indigenous fishes and aquatic plants, have also affected riparian habitats and native aquatic fauna. There are currently 275 active, 13 proposed, and 77 deleted EPA Superfund National Priority List sites in the Coastal Plains ecoregion.

The ecoregion's economy is varied and includes many activities. Agriculture in this ecoregion includes citrus, peanut, sugar cane, tobacco, cattle, poultry, cotton, corn, rice, vegetable, and stone fruit production. Industries include pulp, paper, board, and board wood processing; aluminum production; salt, sulfur, bauxite, and phosphate mining; and chemical and plastics production. The Coastal Plains contain approximately 40% of U.S. petrochemical refinery capacity, much of which is located offshore in the Gulf of Mexico.

This ecoregion also includes many large coastal cities, which contribute to a population of approximately 56,168,000, the largest population of all the WSA ecoregions, representing approximately 19% of the population of the United States.

Summary of WSA Findings

A total of 83 random sites were sampled during the summer of 2004 to characterize the condition of wadeable streams in the Coastal Plains ecoregion. An overview of the WSA survey results for this ecoregion is shown in Figure 28. These results may not be extrapolated to an individual state or stream within the ecoregion because the study design was not intended to characterize stream conditions at these finer scales.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Coastal Plains ecoregion said that the high prevalence of human population centers, agriculture, and industry makes it difficult to find truly undisturbed streams in this ecoregion; therefore, the ecoregion's least-disturbed reference sites are influenced to some degree by human activities.

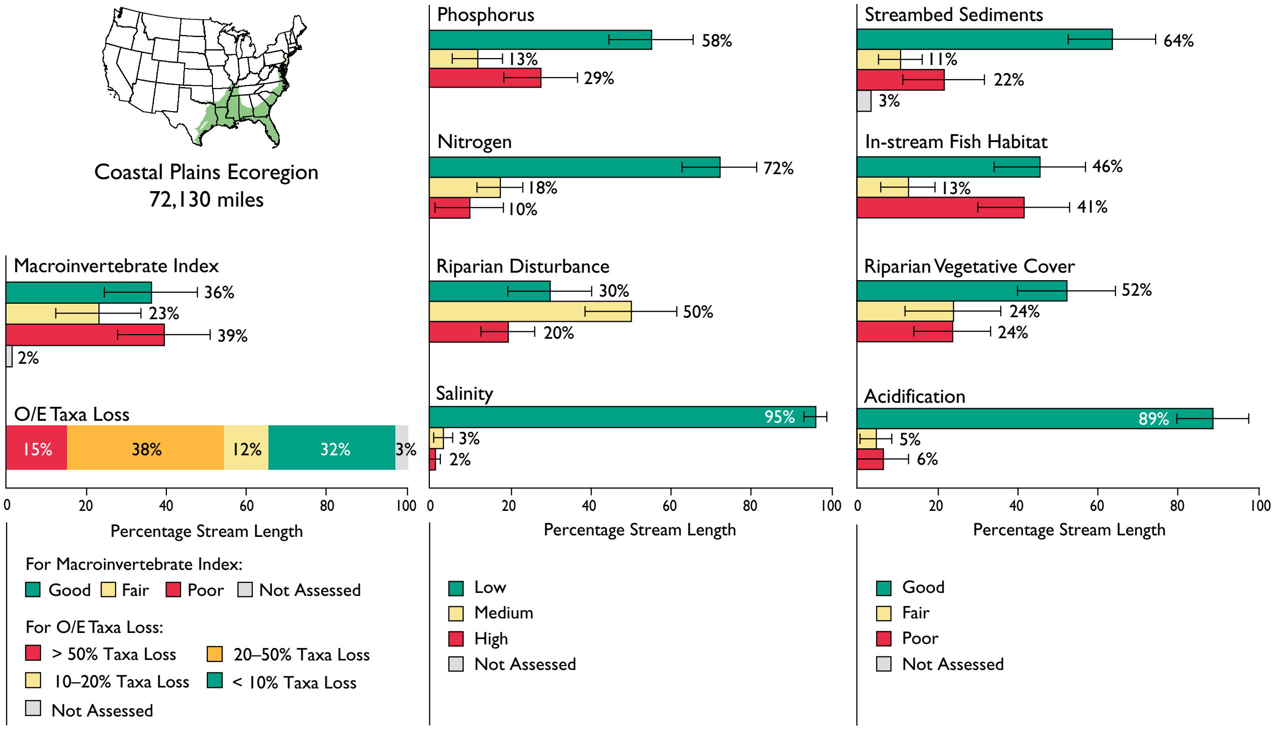


Figure 28. WSA survey results for the Coastal Plains ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

Biological Condition

- The Macroinvertebrate Index reveals that 39% of stream length in the Coastal Plains ecoregion is in poor condition, 23% is in fair or intermediate condition, and 36% is in good condition compared to least-disturbed reference condition. No data were available to evaluate 2% of the ecoregion's stream length.
- The O/E Taxa Loss results show that 65% of stream length in the Coastal Plains ecoregion has lost 10% or more of the macroinvertebrate taxa that are expected to occur, and 15% has lost more than 50% of taxa. These results also indicate that 32% of stream length has retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

Indicators of Stress

Leading indicators of stress in the Coastal Plains ecoregion include total phosphorus, in-stream fish habitat, riparian vegetative cover, and streambed sediments.

- Twenty-nine percent of stream length in the Coastal Plains ecoregion has high phosphorus concentrations, 13% has medium phosphorus concentrations, and 58% has low phosphorus concentrations based on least-disturbed reference condition.
- Ten percent of the ecoregion's stream length has high nitrogen concentrations, 18% has medium nitrogen concentrations, and 72% has low nitrogen concentrations based on least-disturbed reference condition.
- Riparian disturbance, or evidence of human influence in the riparian zone, is at high levels in 20% of stream length, at medium levels in 50% of stream length, and at low levels in 30% of stream length.
- Salinity is found at high or medium levels in 5% of stream length, with the remaining 95% of stream length showing low levels for this indicator.
- Streambed sediments are rated poor in 22% of stream length in the Coastal Plains ecoregion, fair in 11% of stream length, and good in 64% of stream length based on least-disturbed reference condition; no data were available to assess the remaining 3% of stream length.
- In-stream fish habitat is in poor condition in 41% of stream length, fair in 13% of stream length, and good in 46% of stream length, based on least-disturbed reference condition.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 24% of stream length, fair condition for 24% of stream length, and good condition in the remaining 52% of stream length based on least-disturbed reference condition.
- In this ecoregion, the ANC is low enough to result in episodic acidification during rainfall in 6% of stream length. Another 5% of stream length has naturally lower pH.

Upper Midwest Ecoregion

Physical Setting

The Upper Midwest ecoregion covers most of the northern half and southeastern part of Minnesota, two-thirds of Wisconsin, and almost all of Michigan. The land area of the Upper Midwest ecoregion comprises some 160,374 mi^2 (5.3% of the United States). The river systems in this ecoregion empty into portions of the Great Lakes regional watershed and the upper Mississippi River watershed. Major river systems include the upper Mississippi River in Minnesota and Wisconsin; the Wisconsin, Chippewa, and St. Croix rivers in Wisconsin; and the Menominee and Escanaba rivers in Michigan. Streams in the Upper Midwest ecoregion typically drain relatively small catchments and empty directly into the Great Lakes or upper Mississippi River. These streams generally have steep gradients, but their topography and soils tend to slow runoff and sustain flow throughout the year.

The total stream length represented in the WSA for the Upper Midwest ecoregion is 36,547 wadeable stream miles. Sandy soils dominate these waterbodies, with relatively high water quality in streams supporting cold-water fish communities. Important waterbodies in this ecoregion include the Upper Mississippi River system and Lakes Superior, Michigan, Huron, and Erie.

The glaciated terrain of this ecoregion typically consists of plains with some hill formations. Numerous lakes, rivers, and wetlands predominate in most areas. The climate is characterized by cold winters and relatively short, warm summers, with mean annual temperatures ranging from 34 to 54 °F and annual precipitation in the 20- to 47-inch range. Much of the land in this ecoregion is covered by national and state forests, and federal lands account for 15.5% of the area (roughly 25,000 mi^2). Based on satellite images in the 1992 NLCD, the distribution of land cover in this ecoregion is 40% forested, 34% planted/cultivated, and 17% wetlands, with the remaining 9% of the ecoregion comprised of other types of land cover.

Raisin River, MI, in the Upper Midwest ecoregion (Photo courtesy of the Great Lakes Environmental Center).

Biological Setting

Vegetative cover for the Upper Midwest ecoregion is mixed boreal woodland, mixed oak-hickory associations, and conifers, as well as bog and moss barrens. The Great Lakes aquatic ecosystems are subject to increasing intrusion by invasive animal and plant species introduced by ocean shipping. These species include the zebra mussel, the round goby, the river ruffe, the spiny water flea, and Eurasian watermilfoil.

Human Influence

The Upper Great Lakes portion of the Upper Midwest ecoregion was entirely forested in pre-colonial times. Virtually all of the virgin forest was cleared in the 19th and early 20th centuries, and streams and rivers were greatly affected by the logging industry. The upper Mississippi River portion of the Upper Midwest ecoregion was also heavily influenced by logging and agriculture.

Major manufacturing, chemical, steel, and power production (e.g., coal, nuclear, oil) occur in the large metropolitan areas found in the Upper Midwest ecoregion. Other key economic activities are forestry, mining, and tourism. Agriculture includes dairy production, grain crops in the western areas, fruit production around the Great Lakes, and hay and cattle farming throughout the ecoregion. Pulp, paper, and board wood processing are prevalent throughout the northern parts of the ecoregion. The area includes the shipping ports at Duluth, MN, and Superior, WI, as well as cities like Marquette, MI, and Hibbing, MN, which were built up along with the mining industry. The Upper Peninsula of Michigan lies entirely within the Upper Midwest ecoregion, as does Minnesota's Mesabi Range, the largest U.S. iron ore deposit. This area is subject to the environmental effects of mining operations. There are currently 112 active, 1 proposed, and 12 deleted EPA Superfund National Priority List sites in this ecoregion.

The approximate population of this area is 15,854,000, representing approximately 5% of the population of the United States.

Summary of WSA Findings

A total of 56 random sites were sampled in the Upper Midwest ecoregion during the summer of 2004 to characterize the condition of its wadeable streams. An overview of the WSA survey results for the Upper Midwest ecoregion is shown in Figure 29. These results may not be extrapolated to an individual state or stream within the ecoregion because the study design was not intended to characterize stream conditions at these finer scales.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Upper Midwest ecoregion said that some of the ecoregion's least-disturbed streams that serve as a benchmark for reference condition are influenced by some form of human activity or land use; however, most of the least-disturbed reference sites are streams in relatively undisturbed areas in the northern portion of the ecoregion.

Biological Condition

- The Macroinvertebrate Index reveals that 39% of stream length in the Upper Midwest ecoregion is in poor condition, 31% is in fair condition, and 28% is in good condition based on least-disturbed reference condition.
- The O/E Taxa Loss results show that 54% of stream length in the Upper Midwest ecoregion has lost 10% or more of the macroinvertebrate taxa that are expected to occur, and 5% has lost more than 50% of taxa. These results also indicate that 45% of stream length has retained at least 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

Indicators of Stress

Leading indicators of stress in the Upper Midwest ecoregion include total phosphorus, total nitrogen, streambed sediments, and in-stream fish habitat.

- Thirty-eight percent of stream length in the Upper Midwest ecoregion has high phosphorus concentrations, 18% has medium

Figure 29. WSA survey results for the Upper Midwest ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

phosphorus concentrations, and 42% has low phosphorus concentrations based on least-disturbed reference condition.

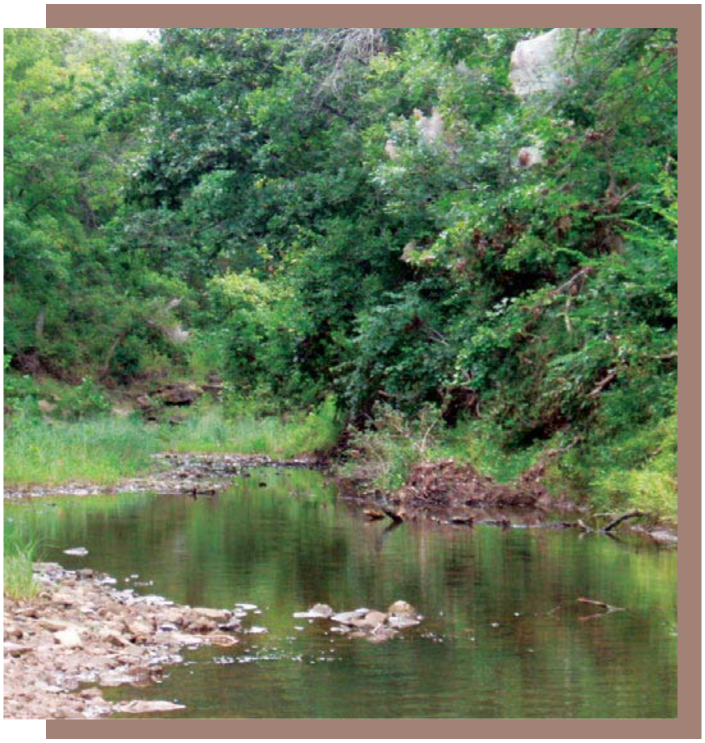
- Twenty-one percent of the ecoregion's stream length has high nitrogen concentrations, 30% of stream length has medium nitrogen concentrations, and 48% of stream length has low nitrogen concentrations based on least-disturbed reference condition.
- Riparian disturbance, or evidence of human influence in the riparian zone, is at high levels in 6% of stream length, at medium levels in 45% of stream length, and at low levels in 49% of stream length.
- Salinity is found at medium levels in 22% of stream length and at low levels in 77% of stream length. None of the steam length of the Upper Midwest ecoregion showed high levels for this indicator.
- Streambed sediments are rated poor in 50% of stream length, fair in 11%, and good in 37%; data for this indicator were not available for 2% of stream length.
- In-stream fish habitat is in poor condition in 17% of stream length, fair in 69% of stream length, and good in 14% of stream length based on least-disturbed reference condition.
- Vegetative cover in the riparian zone along stream banks is in poor condition in 13% of stream length, fair condition in 38% of stream length, and in good condition in 44% of stream length.
- The effects of acidification are not noted for the Upper Midwest ecoregion.

Temperate Plains Ecoregion

Physical Setting

The Temperate Plains ecoregion includes the open farmlands of Iowa; the eastern Dakotas; western Minnesota; portions of Missouri, Kansas, and Nebraska; and the flat farmlands of western Ohio, central Indiana, Illinois, and southeastern Wisconsin. The area of this ecoregion covers some 342,200 mi^2 (11.4% of the United States), with approximately 7,900 mi^2 (2.3%) of land under federal ownership. The ecoregion's terrain consists of smooth plains and numerous small lakes and wetlands. The climate is temperate, with fairly cold winters; hot, humid summers; and mean temperatures ranging from 36 to 55 °F. Annual precipitation in the Temperate Plains ecoregion ranges from 16 to 43 inches.

Many of the rivers in this ecoregion drain into the Upper Mississippi and Ohio regional watersheds, and a few systems empty into the Great Lakes watershed near Toledo, OH; Saginaw, MI; Detroit, MI; and southeastern Wisconsin. Rivers are either supplied by snowmelt or groundwater. Rivers in the tall grass prairie start from prairie potholes and springs and are likely to be ephemeral (flowing for a short time after snowmelt or rainfall). The prairie rivers carry large volumes of fine sediments and tend to be turbid, wide, and shallow. The total stream length represented in the WSA for the Temperate Plains ecoregion is 100,879 wadeable stream miles. Based on satellite images in the 1992 NLCD, the distribution of land cover in this ecoregion is 9% forested and 76% planted/cultivated, with the remaining 15% of the ecoregion comprised of other types of land cover.



Grey Horse Creek, OK, in the Temperate Plains ecoregion (Photo courtesy of Monty Porter).

Biological Setting

Vegetation for the Temperate Plains ecoregion consists primarily of oak, hickory, elm, ash, beech, and maple, with increasing amounts of prairie grasses to the west. Rivers have rich fish fauna with many species, including minnows, darters, killifishes, catfishes, suckers, sunfishes, and black bass. Few species are endemic to the ecoregion.

Human Influence

Pre-settlement vegetation of the area was prairie grass and aspen parkland, but is now comprised of about 75% arable cultivated lands. This ecoregion is rich in agricultural production, including field crops such as corn, wheat, alfalfa, soybeans, flaxseed, and rye, along with vegetable crops such as peanuts and tomatoes. Hog and cattle production and processing are also prevalent. Crops and grazing have reduced natural riparian vegetation cover, increased sediment yield, and introduced pesticides and herbicides into the watershed. Conservation tillage — a reduced-cultivation method — has been implemented in about 50% of crop fields in the Maumee River Basin and in northwestern Ohio tributaries draining to Lake Erie. USGS findings from 1993–1998 in these rivers showed significant decreases in the amounts of suspended sediment. Rivers in the Temperate Plains ecoregion also tend to have high nitrogen concentrations due to nutrients from agriculture and from fertilizer applied to lawns and golf courses in urban areas. In Illinois, where land is intensively developed through urbanization and agriculture, more than 25% of all sizable streams have been channelized, and almost every stream in the state has at least one dam.

Coal mining, petroleum and natural gas production, and zinc and lead mining occur across the Temperate Plains ecoregion. There are very active areas of manufacturing, steel production, and chemical production in the ecoregion's urban centers, with especially high concentrations near Detroit, MI, and the industrial belt from Gary, IN, to Chicago, IL, and Milwaukee, WI. Industrial activities in these large urban centers have contributed sewage, toxic compounds, and silt to river systems. Heavy metals, organochlorines, and PCBs are especially prevalent and persistent river contaminants found in industrial areas; however, many rivers have improved from their worst state in the 1960s. There are currently 133 active, 17 proposed, and 44 deleted EPA Superfund National Priority List sites in the Temperate Plains ecoregion.

The approximate population of this ecoregion is 38,399,000, representing approximately 13% of the U.S. population.

Summary of WSA Findings

A total of 132 random sites were sampled during the summer of 2004 to characterize the condition of wadeable streams throughout the Temperate Plains ecoregion. An overview of the WSA survey results for the Temperate Plains ecoregion is shown in Figure 30. These results may not be extrapolated to an individual state or stream within the ecoregion because the study design was not intended to characterize stream conditions at these finer scales.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Temperate Plains ecoregion said that it is hard to find high-quality reference sites in the ecoregion because even the least-disturbed streams are influenced by a long history of land use. Extensive agriculture and development have influenced virtually all waterbodies in this ecoregion.

Biological Condition

- The Macroinvertebrate Index reveals that 37% of stream length in the Temperate Plains ecoregion is in poor condition, 36% is in fair condition, and 26% is in good condition compared to least-disturbed reference condition.
- The O/E Taxa Loss results show that 39% of stream length in the Temperate Plains ecoregion has lost 10% or more of the macroinvertebrate taxa that are expected to occur, and 10% has lost more than 50% of taxa. These results also indicate that 58% of stream length has retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

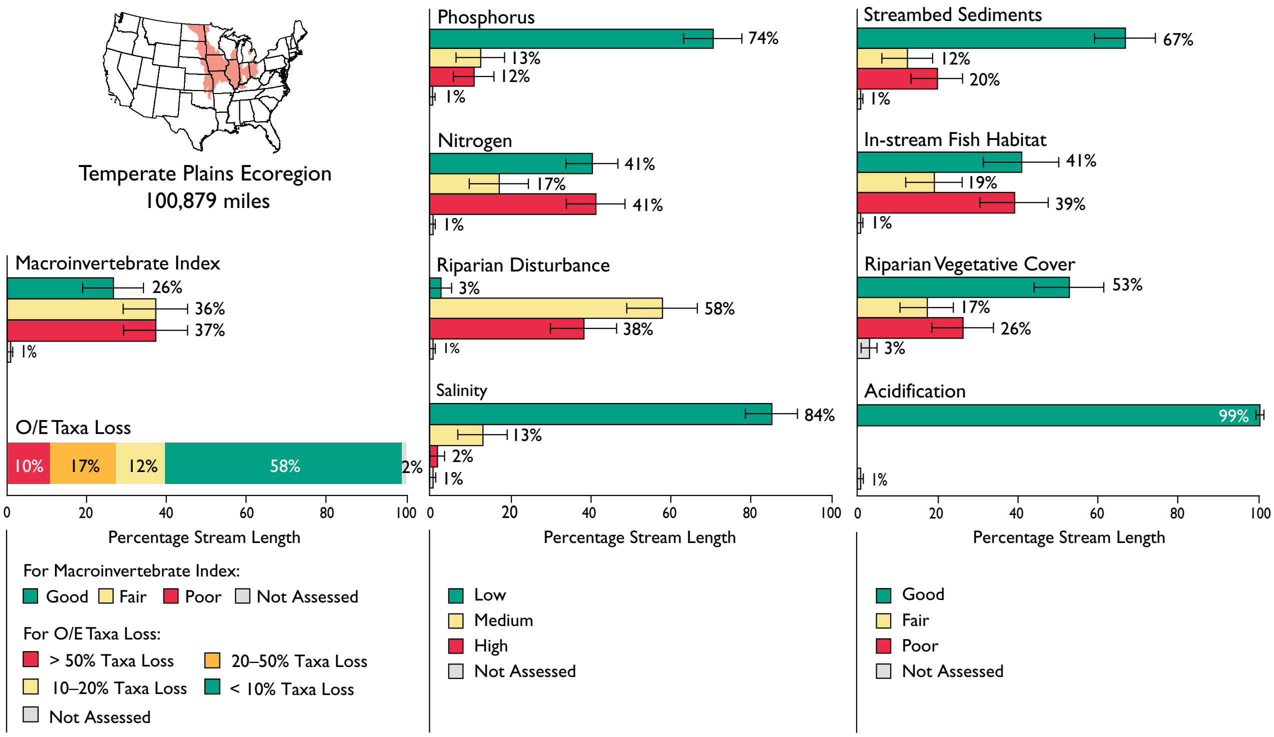


Figure 30. WSA survey results for the Temperate Plains ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

Indicators of Stress

Leading indicators of stress in the Temperate Plains ecoregion include total nitrogen, riparian disturbance, in-stream fish habitat, and riparian vegetative cover.

- Approximately 12% of stream length in the Temperate Plains ecoregion has high phosphorus concentrations, 13% has medium phosphorus concentrations, and 74% has low phosphorus concentrations based on least-disturbed reference condition.
- Approximately 41% of the ecoregion's stream length has high nitrogen concentrations, 17% has medium nitrogen concentrations, and 41% has low nitrogen concentrations based on least-disturbed reference condition.
- Riparian disturbance for this ecoregion is at high levels in approximately 38% of stream length, at medium levels in 58% of stream length, and at low levels in 3% of stream length.
- Salinity is found at high levels in 2% of stream length, at medium levels in 13% of stream length, and at low levels in 84% of stream length.
- Excess streambed sediments affect streams in the Temperate Plains ecoregion to a lesser extent than other physical stressors. Streambed sediments are rated poor in 20% of stream length in this ecoregion, fair in 12%, and good in 67% based on least-disturbed reference condition.

- In-stream fish habitat is in poor condition in 39% of stream length, fair in 19% of stream length, and good in 41% of stream length based on least-disturbed reference condition.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 26% of stream length, fair condition for 17% of stream length, and good condition for 53% of stream length.
- The effects of acidification are not noted for the Temperate Plains ecoregion.

Southern Plains Ecoregion

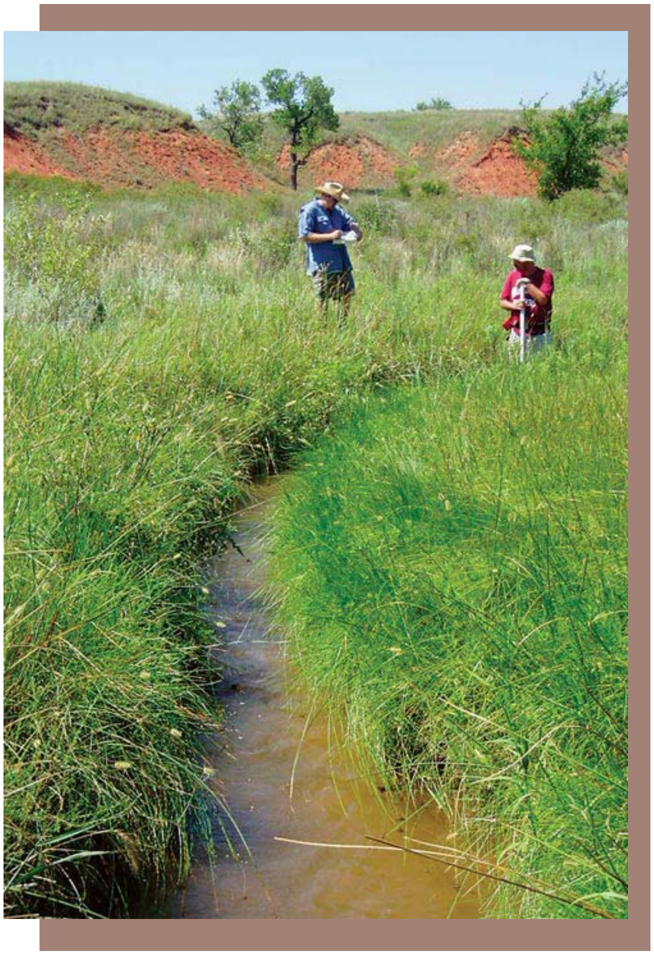
Physical Setting

The Southern Plains ecoregion covers approximately 405,000 mi^2 (13.5% of the United States) and includes central and northern Texas; most of western Kansas and Oklahoma; and portions of Nebraska, Colorado, and New Mexico. The terrain is a mix of smooth and irregular plains interspersed with tablelands and low hills. The Arkansas, Platte, White, Red, and Rio Grande rivers flow through this ecoregion, and most of the great Ogallala aquifer lies underneath this ecoregion. The total stream length represented in the WSA for the Southern Plains ecoregion is 19,263 wadeable stream miles.

Most of the land use is arable and arable with grazing, with desert or semi-arid grazing land in the south. Based on satellite images in the 1992 NLCD, the distribution of land cover in this ecoregion is 45% grassland, 32% planted/cultivated, and 14% shrubland, with the remaining 9% of the ecoregion comprised of other types of land cover. Federal land ownership in this ecoregion totals about 11,980 mi^2 or approximately 3% of the total, the lowest share of all WSA aggregate ecoregions. The climate is dry temperate, with the mean annual temperature ranging from 45 to 79 °F. Annual precipitation for the ecoregion is between 10 and 30 inches.

Biological Setting

Vegetative cover in the northern portion of this ecoregion is mainly short prairie grasses such as buffalo grass, while in the southern portion, grasslands with mesquite, juniper, and oak woody vegetation are common. Coastal vegetation in the southern Plains ecoregion is typically more salt-tolerant in nature.



Commission Creek, OK, in the Southern Plains ecoregion (Photo courtesy of Monty Porter).

Human Influence

The Great Prairie grasslands, which once covered much of the Southern Plains ecoregion, are the most altered and endangered large ecosystem in the United States. About 90% of the original tall grass prairie was replaced by other vegetation or land uses. Agriculture is an important economic activity in this ecoregion and includes sorghum, wheat, corn, sunflower, bean, and cotton production. Livestock production and processing is prevalent, especially goats, sheep, and cattle. The ecoregion contains a sizable portion of U.S. petroleum and natural gas production in Oklahoma, Kansas, and Texas. Electricity in this ecoregion is generated almost exclusively with gas-fired power plants. Some uranium and zinc mining is found in Oklahoma and the Texas panhandle. There are currently 39 active, 5 proposed, and 14 deleted EPA Superfund National Priority List sites in this ecoregion.

The approximate population in this ecoregion is 18,222,000, representing roughly 6% of the population of the United States.

Summary of WSA Findings

A total of 49 random sites were sampled during the summer of 2004 to characterize the condition of wadeable streams throughout the Southern Plains ecoregion. An overview of the WSA survey results for the ecoregion is shown in Figure 31. These results may not be extrapolated to an individual state or stream within the ecoregion because the study design was not intended to characterize stream conditions at these finer scales.

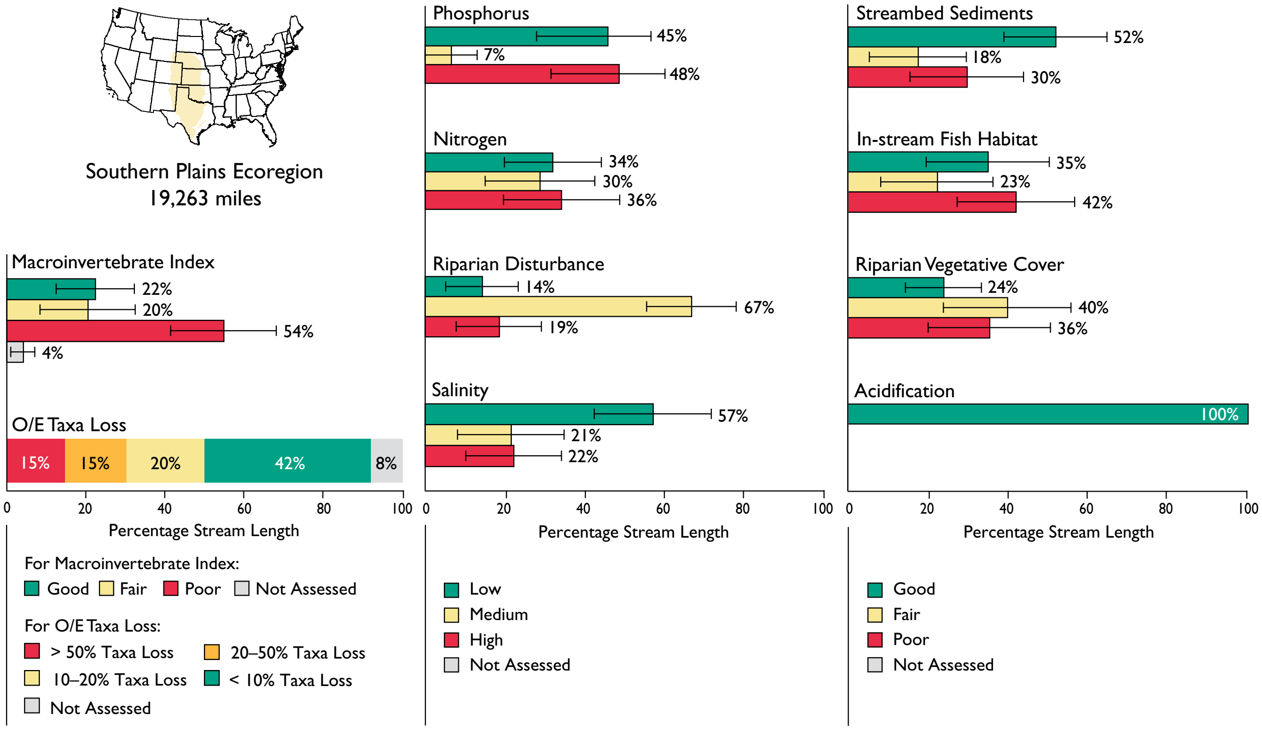


Figure 31. WSA survey results for the Southern Plains ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Southern Plains ecoregion said that no undisturbed streams remain in the ecoregion. The least-disturbed streams are those that retain natural configuration and have riparian buffer zones.

Biological Condition

- The Macroinvertebrate Index reveals that 54% of stream length in the Southern Plains ecoregion is in poor condition, 20% is in fair condition, and 22% is in good condition compared to least-disturbed reference condition. There are no data for the remaining 4% of stream length.
- The O/E Taxa Loss results show that 50% of stream length in the Southern Plains ecoregion has lost 10% or more of the macroinvertebrate taxa expected to occur, and 15% has lost more than 50% of taxa. These results also indicate that 42% of the ecoregion's stream length has retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

Indicators of Stress

The most widespread indicators of stress in the Southern Plains ecoregion include total phosphorus, total nitrogen, in-stream fish habitat, and riparian vegetative cover.

- Forty-eight percent of stream length in the Southern Plains ecoregion has high phosphorus concentrations, 7% has medium phosphorus concentrations, and 45% has low phosphorus concentrations based on least-disturbed reference condition.
- Approximately 36% of the ecoregion's stream length has high nitrogen concentrations, 30% has medium nitrogen concentrations, and 34% has low nitrogen concentrations based on least-disturbed reference condition.
- Riparian disturbance in this ecoregion is at high levels in 19% of stream length. The majority of stream length (67%) has medium levels of riparian disturbance, and only 14% has low levels for this indicator.
- Salinity is found at high levels in 22% of stream length, at medium levels in 21% of stream length, and at low levels in 57% of stream length.
- Streambed sediments are rated poor in 30% of stream length, fair in 18%, and good in 52% based on least-disturbed reference condition.
- In-stream fish habitat is in poor condition in 42% of stream length, fair in 23% of stream length, and good in 35% of stream length based on least-disturbed reference condition.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 36% of stream length, in fair condition for 40% of stream length, and good condition for 24% of stream length.
- The effects of acidification are not noted for the Southern Plains ecoregion.

Northern Plains Ecoregion

Physical Setting

The Northern Plains ecoregion covers approximately 205,084 mi^2 (6.8% of the United States), including the western Dakotas, Montana east of the Rocky Mountains, northeast Wyoming, and a small section of northern Nebraska. Federal lands account for 52,660 mi^2 or a relatively large (25.7%) share of the total area. The Great Prairie grasslands were also an important feature of this ecoregion, but about 90% of these grasslands have been replaced by other vegetation or land use. The ecoregion's terrain is irregular plains interspersed with tablelands and low hills. This ecoregion is the heart of the Missouri River system and is almost exclusively within the Missouri River's regional watershed. The total stream length represented in the WSA for the Northern Plains ecoregion is 13,445 wadeable stream miles.

Land use is arable with grazing or semi-arid grazing. Based on satellite images in the 1992 NLCD, the distribution of land cover in this ecoregion is 56% grassland and 30% planted/cultivated, with the remaining 14% of the ecoregion comprised of other types of land cover. Significant wetlands are also found in the Nebraska Sandhills area. The climate is dry and continental, characterized by short, hot summers and long, cold winters. Temperatures average 36 to 46 °F, and annual precipitation totals range from 10 to 25 inches. High winds are an important climatic factor in this ecoregion. It is also subject to periodic, intense droughts and frosts.

Biological Setting

The predominant vegetative cover for the Northern Plains ecoregion was formerly native short prairie grasses, such as wheat grass and porcupine grass, but now cropland is much more prevalent.

Wolf Creek, McCook County, SD, in the Northern Plains ecoregion (Photo courtesy of Dynamac Corp).

Human Influence

Human economic activity is primarily agriculture, including cattle and sheep grazing, as well as the growing of wheat, barley, and sugar beets. Coal mining occurs in the North Dakota, Montana, and Wyoming portions of the ecoregion. Petroleum and gas production has grown considerably in the Cut Bank region in north-central Montana. There are several large Indian reservations in this ecoregion, including the Pine Ridge, Standing Rock, and Cheyenne reservations in South Dakota and the Blackfeet, Crow, and Fort Peck reservations in Montana. There are currently four active and one proposed EPA Superfund National Priority List sites in this ecoregion.

The approximate population of this ecoregion is relatively small at 1,066,000, or 0.4% of the population of the United States.

Summary of WSA Findings

A total of 98 random sites were sampled during the summers of 2000–2004 to characterize the condition of wadeable streams throughout the Northern Plains ecoregion. An overview of the WSA survey results for the ecoregion is shown in Figure 32. These results may not be extrapolated to an individual state or stream within the ecoregion because the study design was not intended to characterize stream conditions at these finer scales.

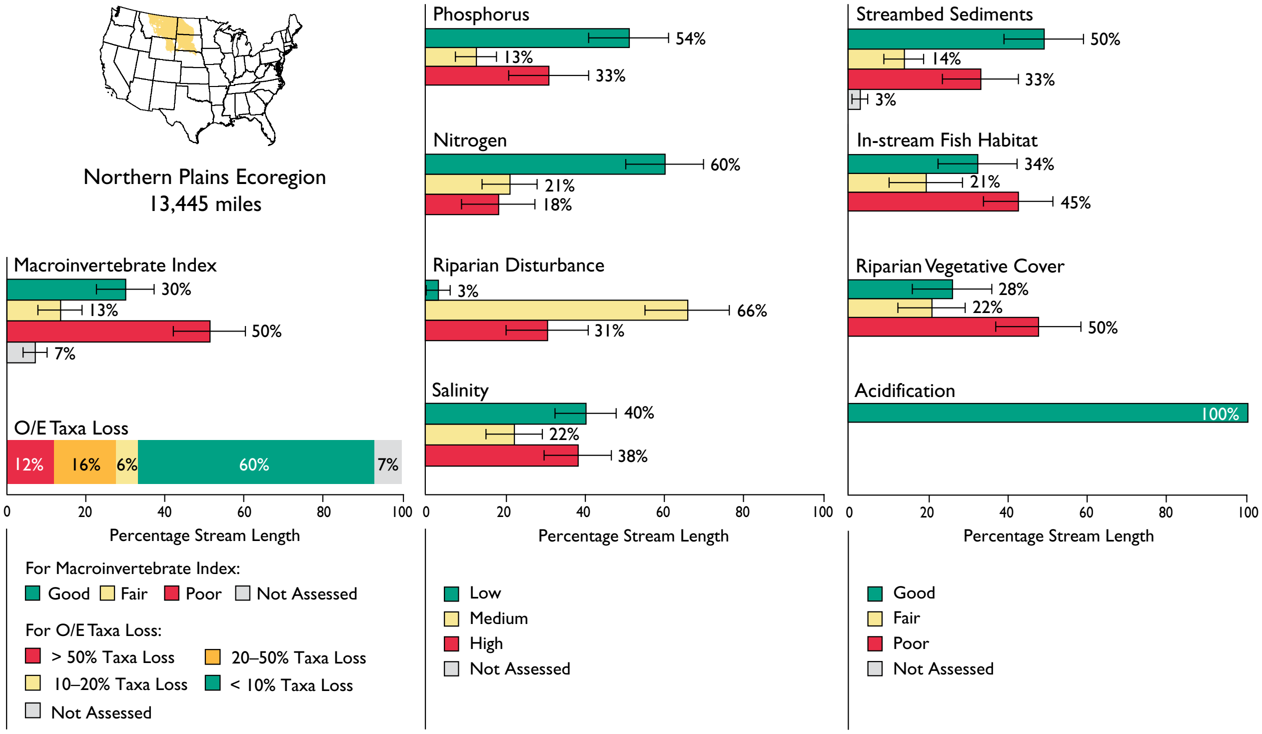


Figure 32. WSA survey results for the Northern Plains ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Northern Plains ecoregion said that although the ecoregion has relatively few undisturbed streams, the majority are in areas of low-level agriculture and pastureland.

Biological Condition

- The Macroinvertebrate Index reveals that 50% of stream length in the Northern Plains ecoregion is in poor condition, 13% is in fair condition, and 30% is in good condition compared to least-disturbed reference condition. There are no data for the remaining 7% of stream length.
- The O/E Taxa Loss results show that 34% of stream length has lost 10% or more of the macroinvertebrate taxa expected to occur, and 12% has lost more than 50% of taxa. These results also indicate that 60% of the ecoregion's stream length has retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

Indicators of Stress

The most widespread indicators of stress in the Northern Plains ecoregion include riparian vegetative cover, in-stream fish habitat, riparian disturbance, and salinity.

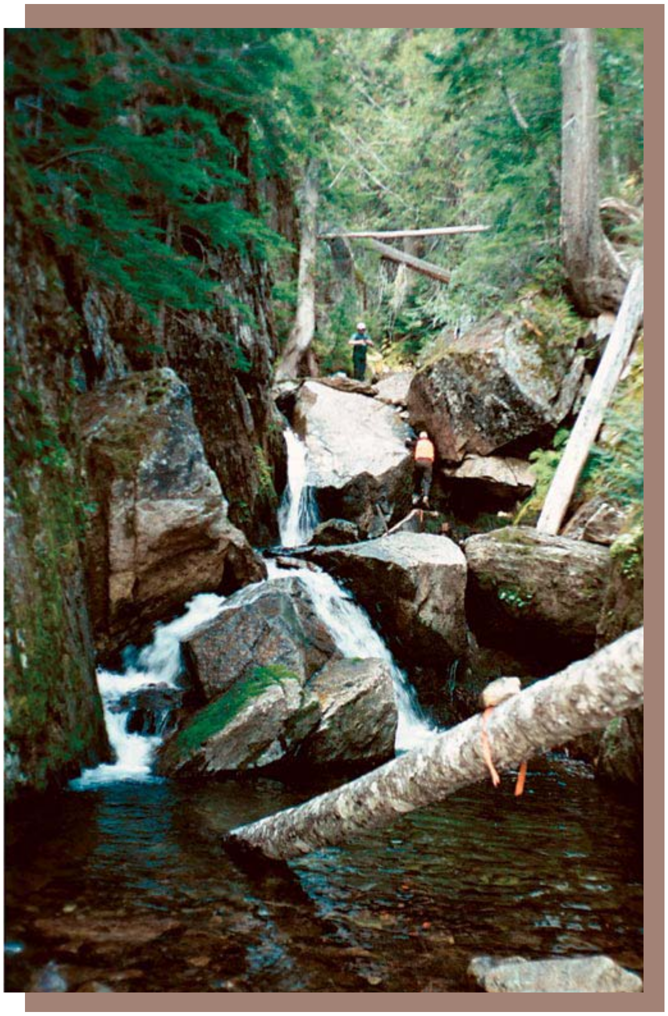
- Thirty-three percent of stream length in the Northern Plains ecoregion has high phosphorus concentrations, 13% has medium phosphorus concentrations, and 54% has low phosphorus concentrations based on least-disturbed reference condition.
- Eighteen percent of the ecoregion's stream length has high nitrogen concentrations, 21% has medium nitrogen concentrations, and 60% has low nitrogen concentrations based on least-disturbed reference condition.
- Riparian disturbance in the Northern Plains ecoregion is at high levels in 31% of stream length, at medium levels in 66% of stream length, and at low levels in 3% of stream length.
- Salinity is a significant stressor in the Northern Plains. Salinity is high in 38% of stream length, medium in 22% of stream length, and low in 40% of stream length.
- Streambed sediments are rated poor in 33% of stream length in the Northern Plains ecoregion, fair in 14%, and good in 50% based on least-disturbed reference condition; data for this indicator were unavailable for 3% of stream length.
- In-stream fish habitat is in poor condition in 45% of stream length, fair in 21% of stream length, and good in 34% of stream length based on least-disturbed reference condition.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 50% of stream length, in fair condition for 22% of stream length, and in good condition for 28% of stream length.
- The effects of acidification are not noted for the Northern Plains ecoregion.

Western Mountains Ecoregion

Physical Setting

The Western Mountains ecoregion includes the Cascade, Sierra Nevada, and Pacific Coast ranges in the coastal states; the Gila Mountains in the southwestern states; and the Bitteroot and Rocky mountains in the northern and central mountain states. This ecoregion covers approximately 397,832 mi^2, with about 297,900 mi^2 or 74.8% classified as federal land — the highest proportion of federal property among all the 9 aggregate ecoregions. The terrain of this area is characterized by extensive mountains and plateaus separated by wide valleys and lowlands. Coastal mountains are transected by numerous fjords and glacial valleys, are bordered by coastal plains, and include important estuaries along the ocean margin. Soils are mainly nutrient-poor forest soils. Based on satellite images in the 1992 NLCD, the distribution of land cover in this ecoregion is 59% forested, 19% shrubland, and 13% grassland, with the remaining 9% of the ecoregion comprised of other types of land cover.

The headwaters and upper reaches of the Columbia, Sacramento, Missouri, and Colorado river systems all occur in this ecoregion. Smaller rivers share many characteristics, starting as steep mountain streams with staircase-like channels and steps and plunge pools, with riffles and pools appearing as slope decreases. Upper river reaches experience debris flows and landslides when shallow soils become saturated by rainfall or snowmelt. The total stream length represented in the WSA for the Western Mountains ecoregion is 126,436 wadeable stream miles.



Unnamed tributary to Lake Creek, Chelan County, WA, in the Western Mountains ecoregion (Photo courtesy of the Washington Department of Ecology).

The climate is sub-arid to arid and mild in southern lower valleys, and humid and cold at higher elevations. The wettest climates of North America occur in the marine coastal rain forests of this ecoregion. Mean annual temperatures range from 32 to 55 °F, and annual precipitation ranges from 16 to 240 inches.

Biological Setting

Rivers in this ecoregion drain dense forested catchments and contain large amounts of woody debris that provide habitat diversity and stability. Rivers reaching the Pacific Ocean historically had large runs of salmon and trout, including pink, chum, sockeye, coho, and chinook salmon, as well as cutthroat and steelhead trout. Many of these anadromous fish populations have been reduced since the time of European settlement due to the effects of overfishing, introduced species, flow regulations, and dams. Spawning habitats in stream pools have been drastically reduced due to increased sediments from logging, mining, and other land use changes.

Human Influence

Deforestation and urbanization continue to alter stream habitats in the mountainous west. The Western Mountains riparian ecosystems first encountered pressure from grazing and mining from the mid-1800s to about 1910 and then from the logging roads and fire management practices that occur to the present day.

Placer mining, which disrupts stream sediment habitats, was once widespread in the Western Mountains ecoregion. Particularly damaging in mountainous areas was the introduction of mercury, which was used extensively in placer mining for gold. Toxic contaminants from mining also include arsenic, antimony, copper, chromium, cadmium, nickel, lead, selenium, silver, and zinc. In addition to mining, other activities such as logging, grazing, channelization, dams, and diversions in the Sierra Nevada area also significantly impacted rivers and streams. Introduced fish provided further stress, with several native fish species threatened or endangered.

The principal economic activities in this ecoregion are high-tech manufacturing, wood processing, international shipping, U.S. naval operations, commercial fishing, tourism, grazing, and timber harvesting. Hydroelectric power generation is prevalent in the Pacific Northwest area and California. Bauxite mining also occurs in the Pacific Northwest portions of the ecoregion. There are currently 74 active, 7 proposed, and 22 deleted EPA Superfund National Priority List sites in the Western Mountains ecoregion.

The approximate population in the Western Mountains ecoregion is 9,742,192, representing approximately 3% of the population of the United States.

Summary of WSA Findings

A total of 529 random sites were sampled during the summers of 2000–2004 to characterize the condition of wadeable streams throughout the Western Mountains ecoregion. This ecoregion had the greatest number of sample sites because all the western states enhanced the scale of the national survey by including additional random sites. Although there are enough sites to develop state-scale estimates of condition, this report did not produce those estimates. The individual states are analyzing the survey results in the context of their own water quality standards and assessment methodologies. An overview of the WSA survey results for the Western Mountains ecoregion is shown in Figure 33. These results may not be extrapolated to an individual state or stream within the ecoregion.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Western Mountains ecoregion said that many least-disturbed streams in the ecoregion are of relatively high quality; however, some of these streams have mining and logging impacts, leading to reference conditions of varying degrees of quality.

Biological Condition

- The Macroinvertebrate Index reveals that 25% of stream length in the Western Mountains ecoregion is in poor condition, 28% is in fair condition, and 46% is in good condition compared to least-disturbed reference condition. There are no data for about 1% of stream length.
- The O/E Taxa Loss results show that 33% of stream length has lost 10% or more of the macroinvertebrate taxa expected to occur, and 5% has lost more than 50% of taxa. These results indicate that 63% of stream length has retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

Indicators of Stress

The most widespread indicators of stress in the Western Mountains ecoregion include total nitrogen, total phosphorus, riparian disturbance, and streambed sediments.

- Sixteen percent of stream length in the Western Mountains ecoregion has high phosphorus concentrations, 25% has medium phosphorus concentrations, and 59% has low phosphorus concentrations based on least-disturbed reference condition.

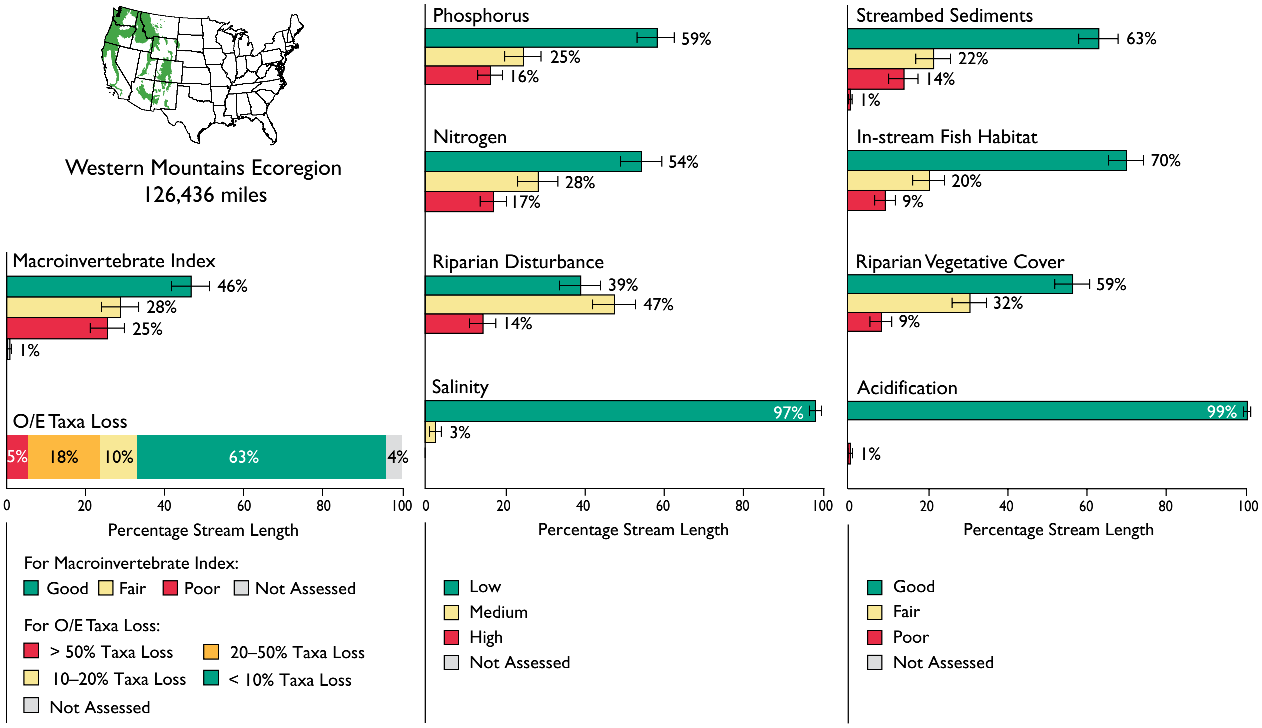
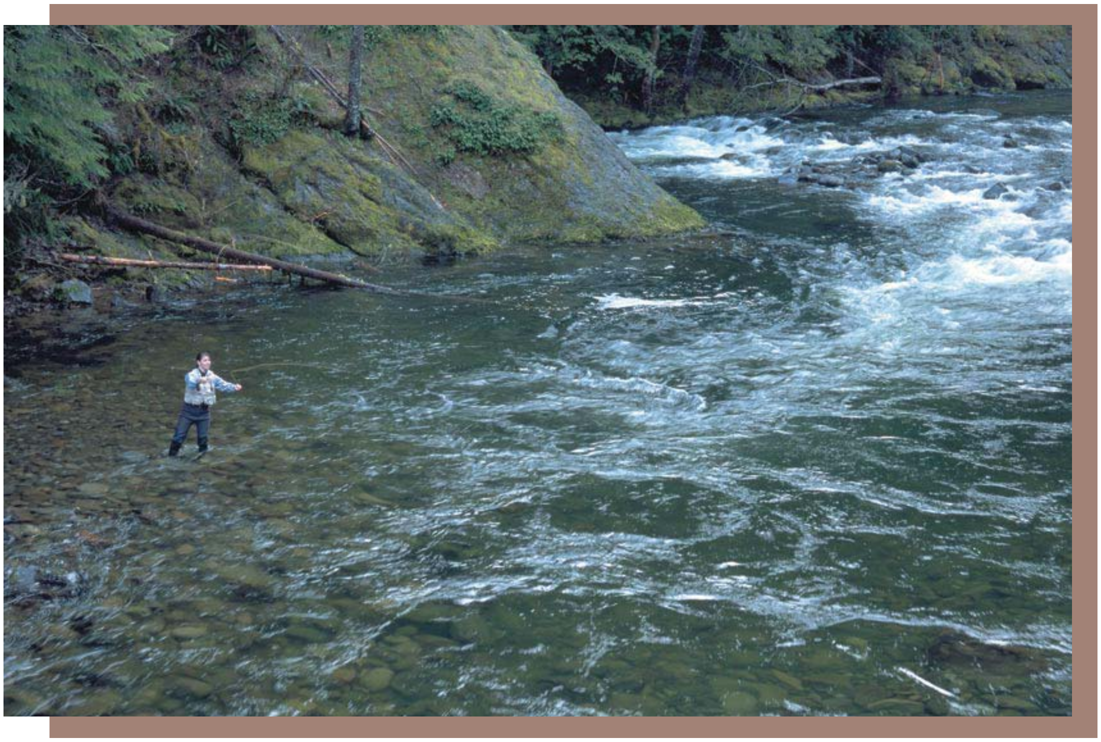


Figure 33. WSA survey results for the Western Mountains ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

- Seventeen percent of the ecoregion's stream length has high nitrogen concentrations, 28% has medium nitrogen concentrations, and 54% has low nitrogen concentrations based on least-disturbed reference condition.
- Riparian disturbance, or evidence of human influence in the riparian zone, is at high levels in 14% of stream length, at medium levels in 47% of stream length, and at low levels in 39% of stream length.
- Levels of salinity are medium in 3% of stream length and low in 97% of stream length. None of the stream length for the Western Mountains ecoregion had high levels of salinity.
- Streambed sediments are rated poor in 14% of stream length in this ecoregion, fair in 22%, and good in the remaining 63%.
- In-stream fish habitat is in poor condition in 9% of stream length, fair in 20% of stream length, and good in 70% of stream length.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 9% of stream length, in fair condition for 32% of stream length, and in good condition for 59% of steam length.
- Acidification is rated poor in nearly 1% of stream length and good in 99% of stream length.



Fishing and tourism are important economic activities in the Western Mountains ecoregion (Photo courtesy of Ron Nichols, U.S. Department of Agriculture National Resources Conservation Service).

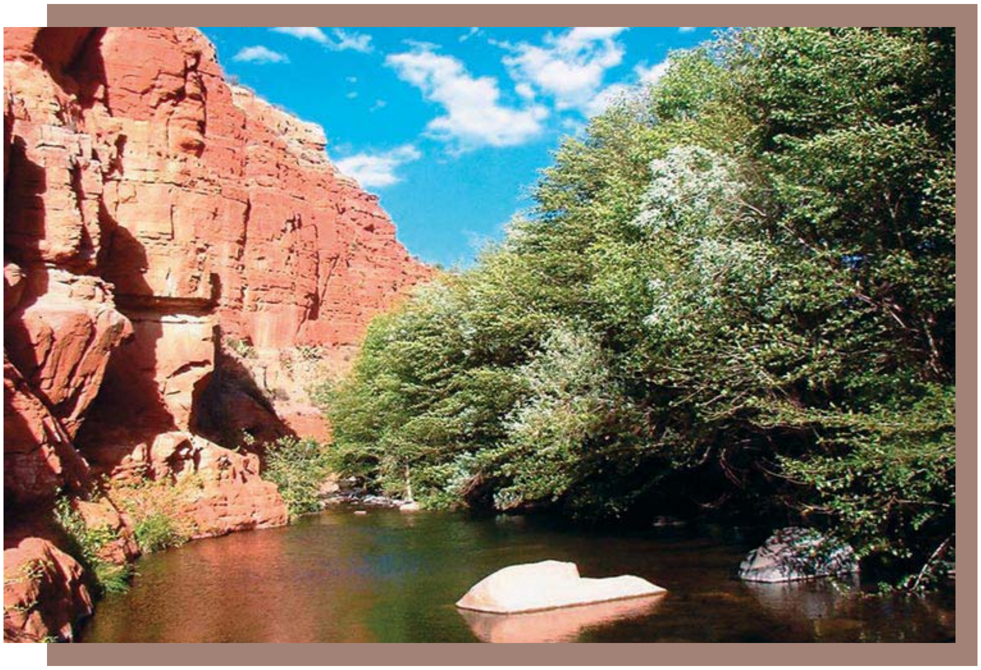
Xeric Ecoregion

Physical Setting

The Xeric ecoregion covers the largest area of all WSA aggregate ecoregions and includes the most total land under federal ownership. This ecoregion covers portions of eleven western states and all of Nevada for a total of about 636,583 mi^2 (21.2% of the United States). Some 453,000 mi^2 or 71.2% of the land is classified as federal lands, including large tracts of public land, such as the Grand Canyon National Park, Big Bend National Park, and the Hanford Nuclear Reservation. Tribal lands include the Navajo, Hopi, and Yakima reservations. Based on satellite images in the 1992 NLCD, the distribution of land cover in this ecoregion is 61% shrubland and 15% grassland, with the remaining 24% of the ecoregion comprised of other types of land cover.

The Xeric ecoregion is comprised of a mix of physiographic features, including plains with hills and low mountains, high-relief tablelands, piedmont, high mountains, and intermountain basins and valleys. The ecoregion includes the flat to rolling topography of the Columbia/Snake River Plateau; the Great Basin; Death Valley; and the canyons, cliffs, buttes, and mesas of the Colorado Plateau. All of the non-mountainous area of California falls in the Xeric ecoregion and is distinguished by a mild Mediterranean climate, agriculturally productive valleys, and large metropolitan areas.

This ecoregion's relatively limited surface water supply contributes to the Upper and Lower Colorado, Great Basin, California, Rio Grande, and Pacific Northwest regional watersheds. Large rivers flow all year, are supplied by snowmelt,



West Clear Creek, Yavapai County, AZ, in the Xeric ecoregion
(Photo courtesy of the Arizona Game and Fish Department/USGS).

and peak in early summer. Small rivers in this ecoregion are mostly ephemeral. Most rivers are turbid because they drain erodable sedimentary rock in a dry climate, where sudden rains flush sediments down small rivers. Rivers are often subject to rapid change due to flash floods and debris flows. In southern areas, dry conditions and water withdrawals produce internal drainages that end in saline lakes or desert basins without reaching the ocean (e.g., Utah's Great Salt Lake). The total stream length represented in the WSA for the Xeric ecoregion is 25,989 wadeable stream miles.

The Xeric ecoregion's climate varies widely from warm and dry to temperate, with mean annual temperatures ranging from 32 to 75 °F and annual precipitation in the 2- to 40-inch range. The dry weather in the Sonoran, Mojave, and Chihuahuan deserts is created by the rain shadows cast by the mountains to the west and is punctuated by heavy, isolated episodic rainfalls.

Biological Setting

Rivers create a riparian habitat oasis for plants and animals in the dry Xeric ecoregion areas. Many fish are endemic, are restricted to the Colorado River basin, and have evolved to cope with warm, turbid waters. Examples include the humpback chub, bonytail chub, Colorado pikeminnow, roundtail chub, razorback sucker, Colorado squawfish, Pyramid Lake cui-ui, and Lahontan cutthroat trout. Most of these fish are threatened or endangered as a result of flow regulations from dams, water withdrawals, and introduced non-native species. Threatened species of fish in desert areas include the Sonora chub and beautiful shiner.

Human Influence

Impacts to the Xeric ecoregion riparian habitats have been heavy in the past 250 years because of water impoundment and diversion; groundwater and surface water extraction; grazing and agriculture; and mining, road development, and heavy recreational demand. Both the least-altered and most-altered pre-settlement natural vegetation types are found in this ecoregion. Riparian habitats in this ecoregion have also been widely impacted by invasive species and contamination from agriculture and urban runoff. Big rivers in the southwestern canyon regions were altered due to large dam construction and large-scale water-removal projects for cities and agriculture, with attendant small streams that experience cycles of draining and filling in response to grazing, groundwater withdrawal, and urbanization. In many desert areas, dissolved solids such as boron, molybdenum, and organophosphates leach from desert soils into irrigation waters. Almost every tributary in California's Central Valley has been altered by canals, drains, and other waterways.

Principal economic activities include recreation and tourism; mining; agriculture; grazing; manufacturing and service industries; agriculture and food processing; aerospace and defense industries; and automotive-related industries. Petroleum production is prevalent in California. Agriculture includes production of a wide range of crops, from wheat, dry peas, lentils, and potatoes to grapes and cotton. Large agricultural irrigation projects include the Salt and Gila valleys and the Imperial and Central valleys in California. There are currently 139 active, 6 proposed, and 24 deleted EPA Superfund National Priority List sites in this ecoregion.

The total population in the Xeric ecoregion is the third largest of all WSA ecoregions at approximately 46,800,000 people, or 16% of the population of the United States.

Summary of WSA Findings

A total of 176 random sites were sampled during the summers of 2000–2004 to characterize the condition of wadeable streams throughout the Xeric ecoregion. An overview of the WSA survey results for the Xeric ecoregion is shown in Figure 34. These results may not be extrapolated to an individual state or stream within the ecoregion.

During a series of WSA workshops conducted to evaluate assessment results, professional biologists working in the Xeric ecoregion said that many of the perennial, least-disturbed streams in this ecoregion have been influenced by past and current human activities.

Biological Condition

- The Macroinvertebrate Index reveals that 39% of stream length in the Xeric ecoregion is in poor condition compared to least-disturbed reference condition, 15% is in fair condition, and 42% is in good condition. There are no data for about 4% of stream length.
- The O/E Taxa Loss results show that 60% of stream length in the Xeric ecoregion has lost 10% or more of the macroinvertebrate taxa expected to occur and 15% has lost more than 50% of taxa. These results also indicate that 34% of stream length has retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

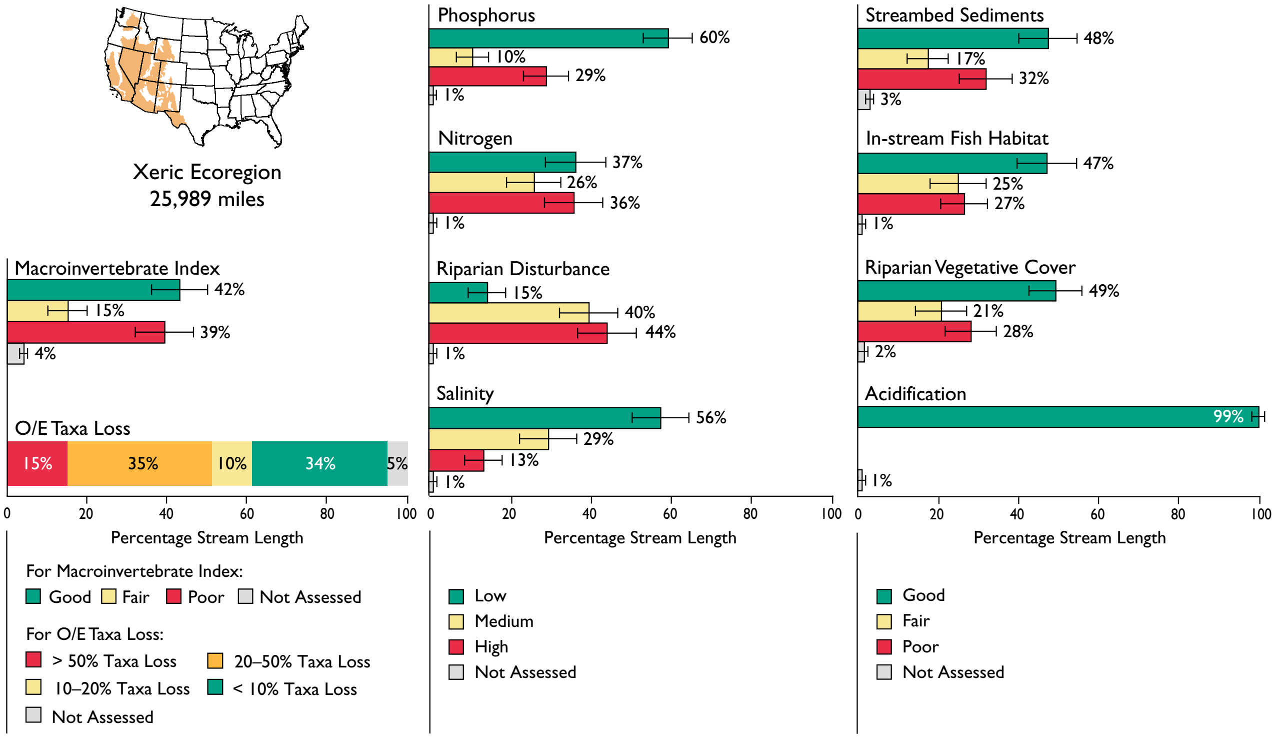


Figure 34. WSA survey results for the Xeric ecoregion (U.S. EPA/WSA). Bars show the percentage of stream length within a condition class for a given indicator. Lines with brackets represent the width of the 95% confidence interval around the percent of stream length. Percents may not add up to 100 because of rounding.

Indicators of Stress

The leading indicators of stress in the Xeric ecoregion include riparian disturbance, total nitrogen, streambed sediments, and in-stream fish habitat.

- Twenty-nine percent of stream length in the Xeric ecoregion has high phosphorus concentrations, 10% has medium phosphorus concentrations, and 60% has low phosphorus concentrations based on least-disturbed reference condition.
- Nitrogen is the leading chemical stressor in the Xeric region. Approximately 36% of stream length has high nitrogen concentrations, 26% has medium nitrogen concentrations, and 37% has low nitrogen concentrations based on least-disturbed reference condition.
- Riparian disturbance, or evidence of human influence in the riparian zone, is the leading physical stressor for the Xeric ecoregion. Riparian disturbance in this ecoregion is at high levels in 44% of stream length, at medium levels in 40% of stream length, and at low levels in 15% of stream length.
- Salinity is rated high in 13% of stream length and medium in 29%, with 56% of stream length showing low levels of this indicator. Data for this indicator were unavailable for approximately 1% of stream length.
- Streambed sediments are rated poor in 32% of stream length in the Xeric ecoregion, fair in 17%, and good in 48%; data on this indicator were unavailable for 3% of stream length.
- In-stream habitat is in poor condition in 27% of stream length, fair in 25%, and good in 47% based on least-disturbed reference condition; data were unavailable for 1% of stream length.
- Vegetative cover in the riparian zone along stream banks is in poor condition in 28% of stream length, in fair condition in 21% of stream length, and in good condition in 49% of stream length.
- The effects of acidification are not noted for the Xeric ecoregion.

The Xeric ecoregion is comprised of a mix of physiographic features, including plains with hills and low mountains, high-relief tablelands, piedmont, high mountains, and intermountain basins and valleys (Photo courtesy of Tim McCabe, U.S. Department of Agricultural Natural Resources Conservation Service).

Chapter 4

Photo courtesy of Jeffrey Cole

Summary and Next Steps

Summary and Next Steps

Summary

The United States covers an enormous and diverse landscape, and not surprisingly, the biological condition of the nation's streams varies widely geographically. Overall, 42% percent of the nation's stream length is in poor biological condition compared to least-disturbed reference condition in each of the WSA ecoregions. The Eastern Highlands region has the largest proportion of streams in poor biological condition (52%), whereas the West has the lowest proportion (27%). In the Plains and Lowlands region, 40% of stream length is in poor biological condition.

Stream miles, represented as stream length, are not evenly distributed across the country. The densest coverage of perennial streams in the lower 48 states is in the Eastern Highlands region, which has approximately 276,362 miles of perennial streams and the smallest land area of the three major regions. The Plains and Lowlands region, which covers the largest portion of the United States, has 242,264 miles of perennial streams. The West has 152,425 miles of streams. It is important to evaluate the survey results in terms of both stream length percentages and absolute stream miles in each condition class. For example, the percentage of stream length in good condition varies dramatically between the West (45%) and Plains and Lowlands regions (29%); however, if these percentages are converted to stream miles, the West has 68,672 miles in good condition, whereas the Plains and Lowlands region has 70,257 miles in good condition.

The WSA finds that the most widespread or common stressors are elevated levels of the nutrients nitrogen and phosphorus, riparian disturbance, and excess streambed sediments. Nationally, 32% of stream length (213,394 miles) has high concentrations of nitrogen compared to least-disturbed reference conditions, and 31% (207,355 miles) has high concentrations of phosphorus. Twenty-six percent of the nation's stream length (171,118 miles) has high levels of riparian disturbance (e.g., human influence along the riparian zone), and 25% (167,092 miles) has streambed sediment characteristics in poor condition. Analysis of the association between stressors and biological condition finds that high levels of nutrients and excess streambed sedimentation more than double the risk of poor biological condition.

The WSA provides the first nationally consistent baseline of the condition of the nation's streams. This baseline will be used in future assessments to evaluate changes in conditions and to provide insights as to the effectiveness of water resource management actions. *Highlight: Acidification Trends and the Clean Air Act* illustrates how this type of survey can be used to evaluate the effectiveness of management actions on improving water quality. States, EPA, and other partners plan to use this approach to implement large-scale assessments of lakes in 2007 and similar assessments of rivers, wetlands, and coastal waters in future years.

Highlight

Acidification Trends and the Clean Air Act

Although this WSA provides a snapshot of the current conditions in the nation's streams, future surveys will allow us to detect trends in stream conditions and in the stressors that affect them. One example in which probability-based survey designs were implemented repeatedly over the course of 10 years has been the evaluation of the responsiveness of acid-sensitive lakes and streams to changes in policy and management actions. Title IV of the 1990 Clean Air Act Amendments (CAAA) set target reductions for sulfur and nitrogen emissions from industrial sources as a means of reducing the acidity in deposition. One of the intended effects of the reductions was to decrease the acidity of low-alkalinity waters. A 2003 EPA report by Stoddard et al., assessed recent changes in surface water chemistry in the northern and eastern United States to evaluate the effectiveness of the CAAA. At the core of the monitoring, known as the Temporally Integrated Monitoring of Ecosystems (TIME) project, was the concept of a probability survey, where a set of sampling sites was chosen to be statistically representative of a target population. In the Northeast (New England and Adirondacks), this target population consists of lakes likely to be responsive to changes in rates of acidic deposition. In the Mid-Atlantic, the target population is upland streams with a high probability of responding to changes in acidic deposition. Repeated surveys of this population allowed an assessment of trends and changes in the number of acidic systems during the past decade. The trends reported in the following table are for recovery from chronic acidification. The analysis found that during the 1990s, the amount of acidic waters in the target population declined. The number of acidic lakes in the Adirondacks dropped by 38%, and the number of acidic lakes in New England dropped by 2%. The length of acidic streams declined by 28% in the Mid-Atlantic area.

Estimates of change in number and proportion of acidic surface waters in acid-sensitive regions of the northern and eastern United States. Estimates are based on applying current rates of change in Gran ANC[a] to past estimates of population characteristics from probability surveys.

Region	Number of Lakes	Number Acidic[b]	% Acidic[c]	Time Period of Estimate	Current Rate of ANC Change[d]	Estimated Number Currently Acidic[e]	Current % Acidic	% Change in Number of Acidic Systems
New England	6,834 lakes	386 lakes	5.6%	1991–1994	+0.3	374 lakes	5.5%	-2%
Adirondacks	1,830 lakes	238 lakes	13.0%	1991–1994	+0.8	149 lakes	8.1%	-38%
Mid-Atlantic	42,426 km	5,014 km	11.8%	1993–1994	+0.7	3,600 km	8.5%	-28%

[a] For both Northeast lakes and Mid-Atlantic streams, waterbodies with ANC (using the analytical technique of Gran titration, with the result known as "Gran ANC") of < 100 μeq/L are particularly vulnerable.
[b] Number of lakes/streams with Gran ANC < 0 in past probability survey (data collected at "Time Period of Estimate" in column 5).
[c] Percent of population (from Column 2) with Gran ANC < 0 in past probability survey (data collected at "Time Period of Estimate" in column 5).
[d] Based on regional trends in μeq/L/year.
[e] Based on trends from repeated surveys through 2001.

Next Steps

In addition to characterizing the biological condition of the nation's stream resources, the WSA provides a rich data set that has sparked interest in many additional areas of investigation. These include the following:

- **Support Protection and Restoration Actions** – The WSA finds that between 25 and 32% of stream length is rated poor due to high levels of nutrients or excess streambed sedimentation. These streams are two times more likely to score poor for biological condition than streams with low levels of these parameters. This national-scale finding reinforces reports from states and the USGS on specific watersheds and stream segments that identify nutrients and streambed sedimentation as leading water quality stressors. EPA is pursuing opportunities to use the WSA data in combination with other data to inform decision-makers responsible for water resource protection and restoration actions. Specific actions in the short term include analyzing the WSA dataset to determine associations between watershed characteristics (e.g., size, slope, and soil type) to help target where improvements are needed; using these characteristics in conjunction with information on the effectiveness of best management practices (BMPs) to help identify successful non-point source pollution controls; and supporting states' development of water quality standards for nutrients and sediments.
- **Future Designs** – It is clear that future surveys will continue to be based on sample survey designs and that the detection of changes and trends will be of greater interest; therefore, future survey designs will include provision for estimating both current status and future trends. This will require a determination of the number of sites that are revisited versus new sites. Current analyses of variance components suggest that in future surveys, a substantial percentage of the sites (possibly 20–50%) should be replaced with new sites and that this replacement should continue with each new survey. This replacement will help detect change; incorporating new sites will improve future status assessments and reduce the likelihood that bias will be introduced by repeated sampling of the same locations. As individual states and tribes begin adopting sample survey designs into their programs, the results from their efforts can be incorporated into the national assessments.
- **Indicators** – This initial assessment was unable to incorporate a large set of biological and stressor indicators because of a short planning timeline. In future national stream surveys, the WSA will consider including fish assemblages, algal assemblages (e.g., periphyton in streams), fish tissue contamination by metals and organics, and/or sediment contamination assessed through either sediment metal and organic chemistry or sediment toxicity tests. It will also be possible to add emerging stressor indicators of concern. This will allow for a more comprehensive assessment of both the conditions in wadeable streams and the stressors potentially affecting them.
- **Field Protocols** – The field protocols used for the WSA are widely used and were well tested across the country. These protocols have demonstrated a strong ability to detect environmental signals against the background

of natural variability. For this initial assessment of wadeable streams, using the same protocols across the country reduced the complexity of interpreting the results; however, for future national stream surveys, the use of different yet comparable methods will be evaluated for different types of streams (e.g., low gradient vs. high gradient). EPA and the states will also explore integrating and sharing data from multiple sources, as well as options to improve sample collection methods.

- **Reference Conditions** – Stream ecologists and state and federal managers agree that they should be able to describe least-disturbed reference condition at a more refined spatial scale than that of the nine regions presented in the WSA. To do so will require substantial coordinated efforts among state, tribal, and federal partners. There are also likely to be some regions of the country in which land-use changes have been so dramatic that even the "best" streams may have experienced substantial chemical, physical, and biological degradation. Additional research will be required to provide a better solution to setting expected conditions for those regions of the country.
- **Stressor Ranking** – The presentation on stressors in the WSA showed both their extent (i.e., the percent of stream length with excessive levels of the stressors) and relative risk (i.e., the increased chance of finding poor biological condition). To make the best use of this information, the WSA must look for stressors that have both high relative risk and large extent. The human health assessment community combines these two sets of information into a single number called the "population attributable relative risk." If, during investigation, this summary number proves reliable for ecological studies, it will simplify the ranking of stressors in future assessments. However, use of more than one biological assemblage in future assessments will result in multiple relative risk values, one for each biological indicator. It would

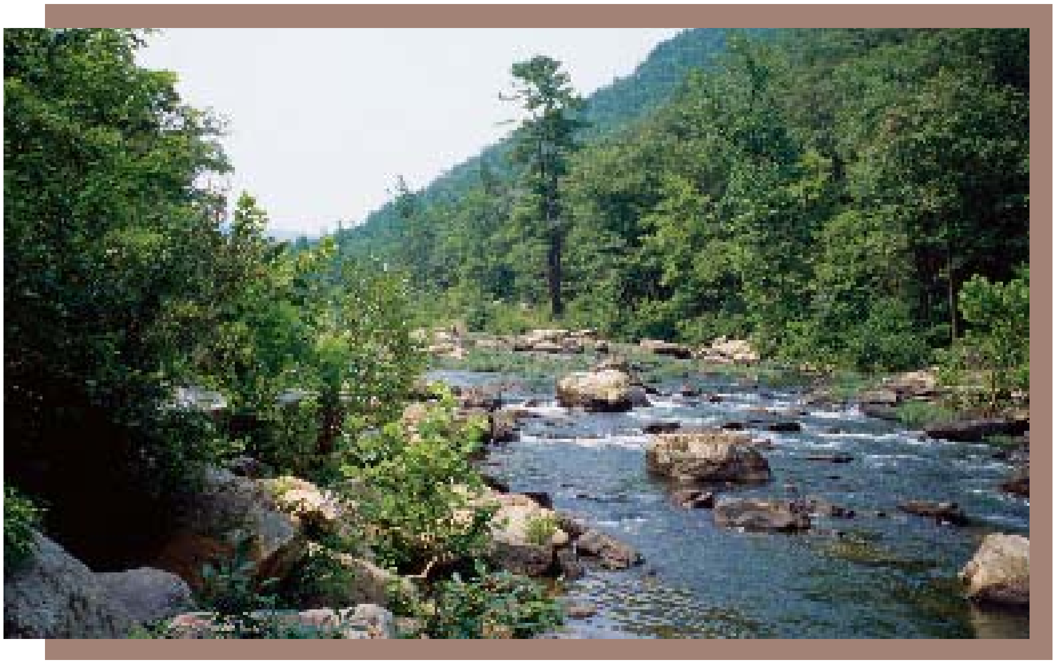


Photo courtesy of Michael L. Smith, FWS

not be surprising if EPA and its partners find that the relative risk posed by each stressor depends on the biological community being evaluated. Although these added numbers may complicate the ranking of stressors, they will also aid in understanding which component of the stream biota is sensitive to each stressor and will provide additional options for management.

- **Future National Assessments** – EPA and its state, tribal, and federal partners will produce national assessments of waterbody types on a yearly cycle. For lakes and reservoirs, a field survey will occur in 2007 with a national assessment report of the results in 2009. Rivers will be surveyed in 2008, and a national assessment report will follow in 2010. Wadeable streams will be surveyed again in 2009, and the assessment report that follows in 2011 will include all flowing waters – both rivers and streams. That report will also evaluate any changes in biological condition that occurred in streams. An NCCR assessment will be repeated in 2012, with the results of the field survey from 2010. Wetlands will be surveyed during the 2011 sampling season, followed by a national assessment report in 2013. From that point on, the surveys and national assessment reports will be repeated in sequence, with changes and trends becoming a greater focus for each resource survey.

The continued utility of these national surveys and their assessment reports requires continued consistency in design, as well as in field, lab, and assessment methods from assessment to assessment; however, the surveys must also provide flexibility that allows the science of monitoring to improve over time. Maintaining consistency while allowing flexibility and growth will be one of the many challenges facing the national assessment program in coming years.

This national survey would not have been possible without the involvement of hundreds of dedicated scientists working for state, tribal, and federal agencies and universities across the United States. Future surveys will rely on this continued close collaboration, a free exchange of knowledge, and a deep well of energy and enthusiasm. It is EPA's goal that participants translate the expertise they gained through these national surveys to studies of their own waters and use this substantial and growing baseline of information to evaluate the success of efforts to protect and restore the quality of the nation's waters.

Photo courtesy of National Park Service

Glossary of Terms

Benthic macroinvertebrates: Aquatic larval stages of insects such as dragonflies; aquatic insects such as aquatic beetles; crustaceans such as crayfish; worms; and mollusks. These small creatures live throughout the stream bed attached to rocks, vegetation, and logs and sticks or burrowed into stream bottoms.

Biological assemblages: Key groups of animals and plants—such as benthic macroinvertebrates, fish, or algae—that are studied to learn more about the condition of water resources.

Biological integrity: State of being capable of supporting and maintaining a balanced community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.

Ecoregions: Ecological regions that are similar in climate, vegetation, soil type, and geology; water resources within a particular ecoregion have similar natural characteristics and similar responses to stressors.

In-stream fish habitat: Areas fish need for concealment and feeding. These areas include large wood within the stream banks, boulders, undercut banks, and tree roots.

Intermittent (ephemeral) streams: Streams that flow only during part of the year, such as in the spring and early summer after snowmelt.

Macroinvertebrate Index of Biotic Condition: The sum of a number of individual measures of biological condition, such as the number of taxa in a sample, the number of taxa with different habits and feeding strategies, etc.

National Hydrography Dataset: Comprehensive set of digital spatial data—based on U.S. Geological Survey 1:100,000 scale topographic maps—that contains information on surface water features such as streams, rivers, lakes, and ponds.

Nutrients: Substances such as nitrogen and phosphorus that are essential to life but can overstimulate the growth of algae and other plants in water. Excess nutrients in streams and lakes can come from agricultural and urban runoff, leaking septic systems, sewage discharges, and similar sources.

O/E (Observed/Expected) Ratio of Taxa Loss: A ratio comparing the number of taxa expected (E) to exist at a site to the number that are actually observed (O). The taxa expected at individual sites are based on models developed from data collected at reference sites.

Perennial streams: Streams that flow continuously throughout the year.

Physical habitat: For streams and rivers, the area in and around the stream or river, including its bed, banks, in-stream and overhanging vegetation, and riparian zone.

Probability-based design: A type of random sampling technique in which every element of the population has a known probability of being selected for sampling.

Reach: A discrete segment of a stream.

Reference condition: The least-disturbed condition available in an ecological region; determined based on specific criteria and used as a benchmark for comparison with other sample sites in the region.

Riparian: Pertaining to a stream or river and its adjacent area.

Riparian disturbance: A measure of the evidence of human activities in and alongside streams, such as dams, roadways, pastureland, and trash.

Riparian vegetative cover: Vegetation corridor alongside streams and rivers. Intact riparian vegetative cover reduces pollution runoff, prevents streambank erosion, and provides shade, lower temperatures, food, and habitat for fish and other aquatic organisms.

Stream order: Stream size, based on the confluence of one stream with another. First-order streams are the origin or headwaters. The confluence or joining of two 1st-order streams forms a 2nd-order stream, the confluence of two 2nd-order streams forms a 3rd-order stream, and so on.

Streambed sediments: Fine sediments and silt on the streambed. In excess quantities, they can fill in the habitat spaces between stream pebbles, cobbles, and boulders and suffocate macroinvertebrates and fish eggs.

Stressors: Factors that adversely effect—and therefore degrade—aquatic ecosystems. Stressors may be chemical (e.g., excess nutrients), physical (e.g., excess sediments on the streambed), or biological (e.g., competing invasive species).

Taxa: Plural of taxon; groupings of living organisms, such as phylum, class, order, family, genus, or species. Scientists organize organisms into taxa in order to better identify and understand them.

Transect: A path or line along which one counts and studies various aspects of a stream, river, or other study area.

Wadeable streams: Streams that are small and shallow enough to adequately sample by wading, without a boat.

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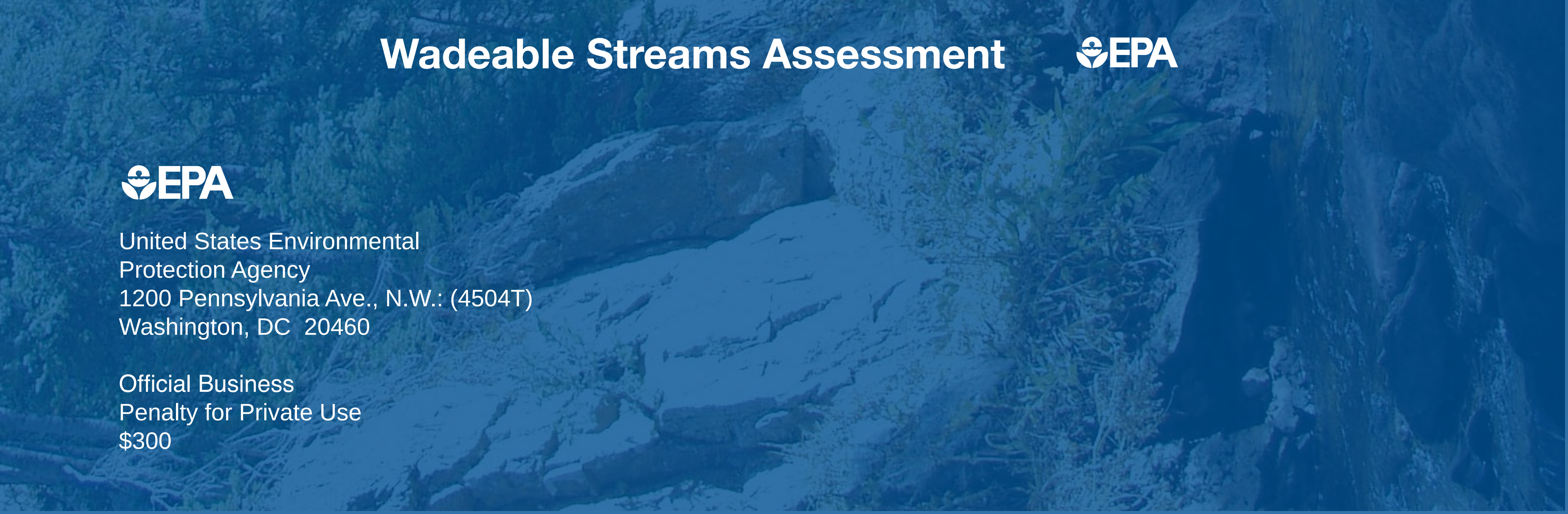

Wadeable Streams Assessment

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