United States
Environmental
Protection Agency

Office of Water
Washington, DC 20460

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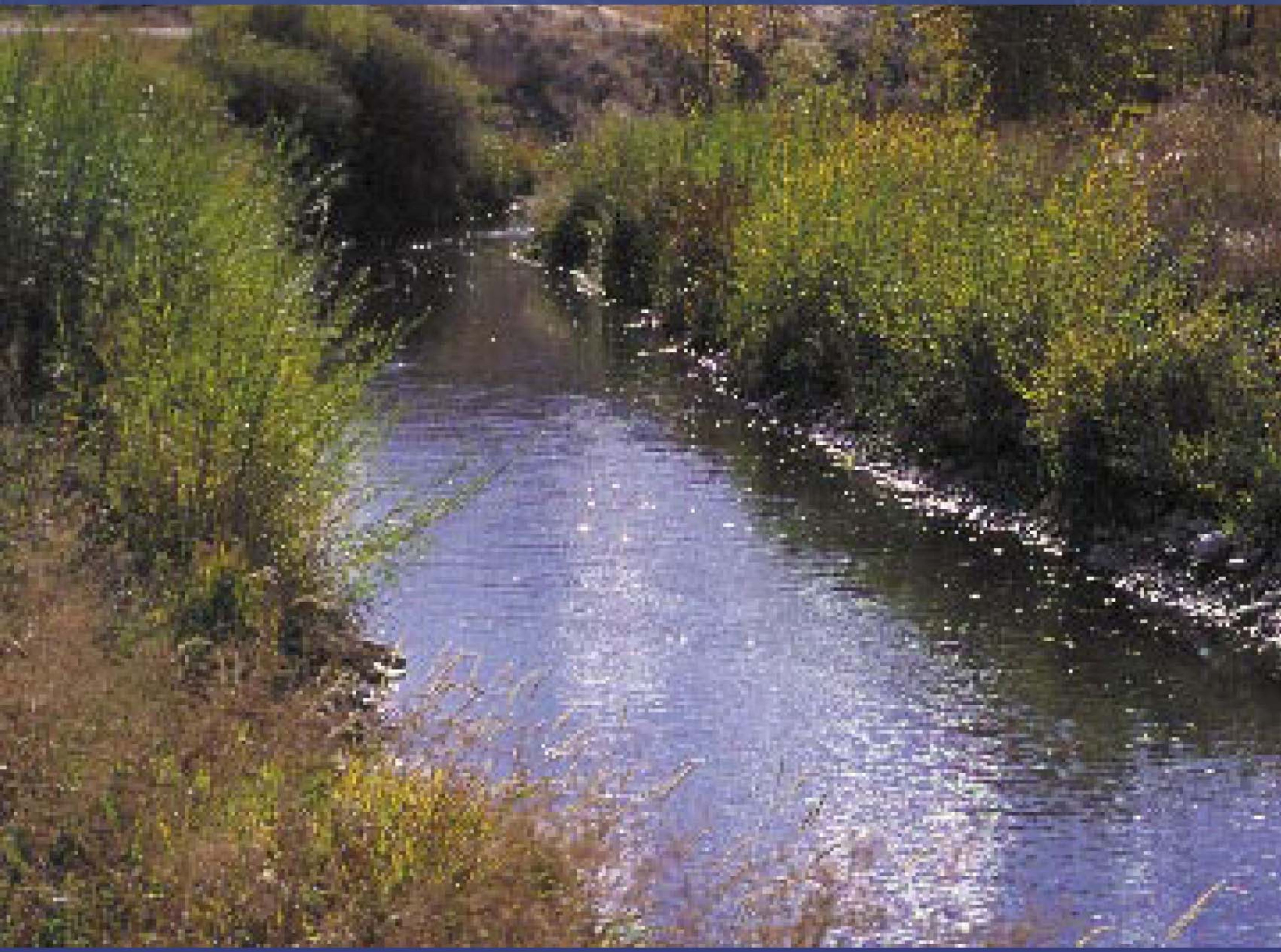
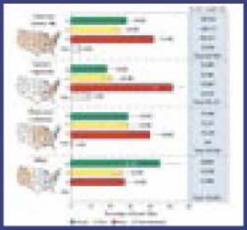
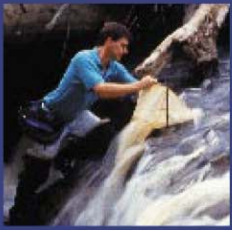
EPA

Wadeable Streams Assessment

A Collaborative Survey of the Nation's Streams







Draft Wadeable Streams Assessment

A Collaborative Survey of the Nation's Streams

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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

Arkansas Department of Environmental Quality

Arizona Game and Fish Department

California Department of Fish & Game

California Water Board

Colorado Department of Public Health & Environment

Colorado Division of Wildlife

Connecticut Department of Environmental Protection

Delaware Department of Natural Resources & Environmental Control

Georgia Department of Natural Resources

Iowa Department of Natural Resources

Idaho Department of Environmental Quality

Illinois Environmental Protection Agency

Idaho Environmental Management

Kansas Department of Health and Environment

Kentucky Division of Water

Louisiana Department of Environmental Quality

Maryland Department of Natural Resources

Maine Department of Environmental Protection

Michigan Department of Environmental Quality

Minnesota Pollution Control Agency

Missouri Department of Conservation

Mississippi Department of Environmental Quality

Montana Department of Environmental Quality

North Carolina Department of Water Quality

Nevada Division of Environmental Protection

New Hampshire Department of Environmental Services

New Jersey Department of Environmental Protection

New Mexico Environment Department

North Dakota Department of Health

New York Department of Environmental Conservation

Oklahoma Conservation Commission

Oklahoma Water Resources Board

Ohio Environmental Protection Agency

Oregon Department of Environmental Quality

Pennsylvania Department of Environmental Protection

South Carolina Department of Health & Environmental Control

South Dakota Department of Environment & Natural Resources

South Dakota Game, Fish & Parks

Tennessee Department of Environment & Conservation

Texas Commission of Environmental Quality

Utah Division of Water Quality

Virginia Department of Environmental Quality

Vermont Department of Environmental Conservation
Washington State Department of Ecology
Wisconsin Department of Natural Resources
West Virginia Department of Environmental Protection
Wyoming Department Environmental Quality
Fort Peck Assiniboine and Sioux Tribes
Guam EPA
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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, 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 Sickel, 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 Environment 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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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 American journalist Charles Kuralt reflects on the central role rivers and streams have played in shaping the history and character of our nation. Because families and communities are dependent on these waterbodies for their health and survival, the condition of these waterbodies, as well as how we protect them, reflects our values and choices as a society.

This Wadeable Streams Assessment (WSA) provides the first statistically defensible summary of the condition of the nation's streams and small rivers, which are so integrally tied to our history. This report brings the results of this ground-breaking study to the American public.

In the 35 years since the passage of the Clean Water Act (CWA), the U.S. Congress, the 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? Is the problem widespread or does it occur in "hotspots"? Which environmental stressors affect the quality of the nation's streams and rivers, and which are most likely to be detrimental? This WSA presents the initial results of what will be a long-term partnership between EPA, the states, tribes, and other federal agencies to answer these questions.

This assessment encompasses the wadeable streams and rivers that account for a vast majority of the length of flowing waters in the United States. To perform this assessment, EPA, the states, and tribes collected chemical, physical, and biological data at more 1,392 wadeable perennial stream locations to determine the biological condition of these waters and the most important factors affecting their water quality. Teams collected samples at sites chosen using an innovative 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, within each of three major climatic and landform regions, and nine ecological regions.

The information provided in this report fills an important gap in meeting the requirements of the CWA. The purpose of this assessment is fourfold:

- Report on the ecological condition of all wadeable, perennial streams and rivers within the conterminous United States. (Pilot projects are 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 state and tribal capacity to include these design and measurement tools in their water quality monitoring programs so that future assessments will be ecologically and statistically comparable, both regionally and nationally.

The results of this survey show that 42% of the U.S. stream miles are in poor condition compared to best available reference sites in their ecological regions, 25% are in fair condition, and 28% are in good condition (Figure ES-1). Five percent of U.S. stream miles were not assessed.

Three major regions were outlined for this assessment: the Eastern Highlands, the Plains and Lowlands, and the West. Of these three regions, the West is in the best condition, with 45% of the length of wadeable flowing waters in good condition. The Eastern Highlands region presents the most concerns, with only 18% of the length of wadeable streams and rivers in good condition, and 52% of its length of wadeable streams and rivers in poor condition. In the Plains and Lowlands region, water quality conditions are between the other two regions, with almost 30% of the length of wadeable streams and rivers in good condition and 40% in poor condition.

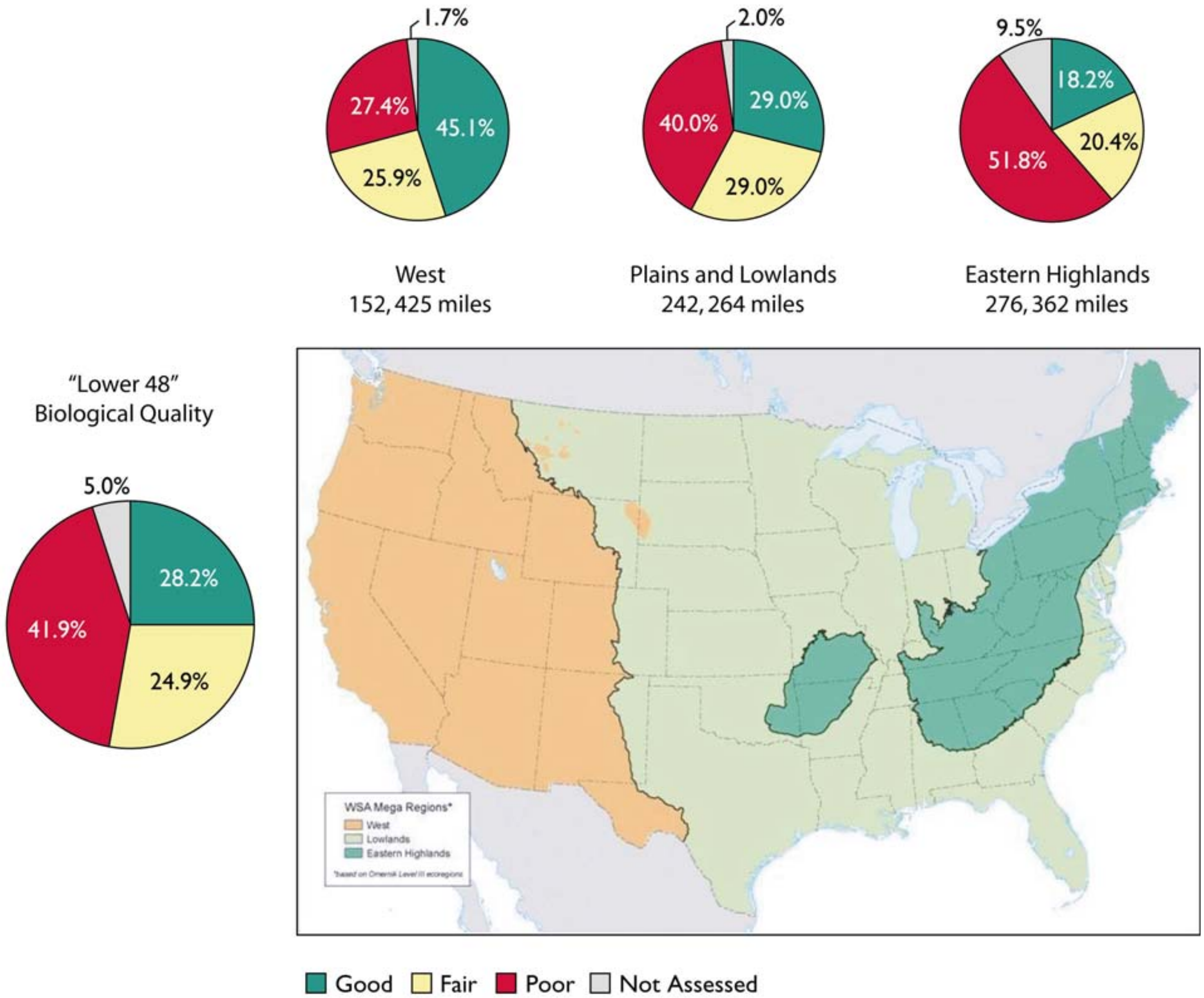

Figure ES-1. Condition of wadeable streams.

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; streams scoring poor for these stressors were at 2 to 3 times higher risk of having poor biological condition than streams that scored in the good range for the same stressors. (Figure ES-2).

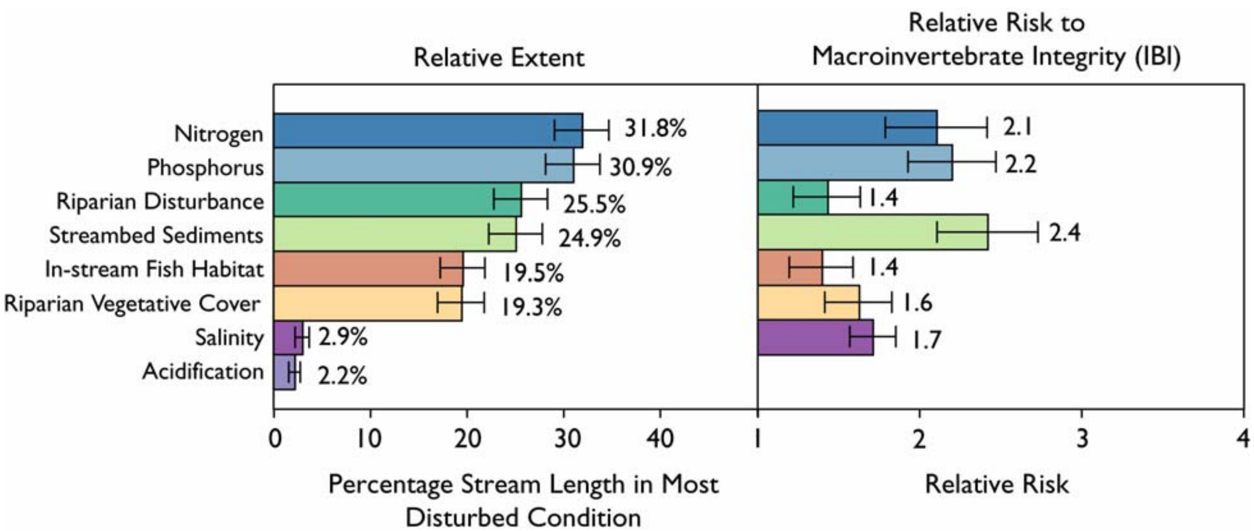

Figure ES-2. Relative extent and relative risk for anthropogenic stressors impacting the nation's waters.

Understanding the current condition of the nation's wadeable streams and rivers is critical in 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 this WSA, and others like it in the future, will inform the public, water quality managers, and elected officials of the effectiveness of programs to protect and restore water quality and the potential need to refocus these efforts.

Readers who wish to learn more about the technical background of this assessment are directed to literature cited in the References section and to the appendix located at the end of this report.

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Introduction

In 1972, Congress enacted the landmark Clean Water Act (CWA) to protect our 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 have reviewed the available data and concluded that we were unable to provide Congress and the public with adequate information regarding the condition of the nation's waterbodies.

The General Accounting Office in 2000 issued a report noting that EPA and the states cannot make statistically valid inferences about water quality and lack data to support management decisions. In 2001, a National Research Council report 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.

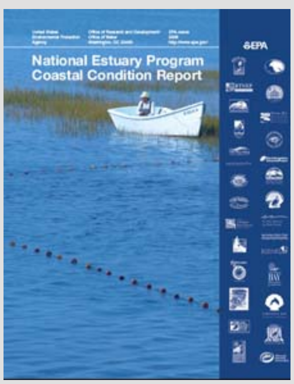
Following the 2002 release of the Heinz Center's *The State of the Nation's Ecosystems,* the national newspaper *USA Today* published an editorial discussing the lack of environmental information available to the public. This editorial emphasized that agencies have failed to fund the collection of necessary environmental data despite very effective collection of comparable information on the nation's economy, population, energy usage, human health, and crime. 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).

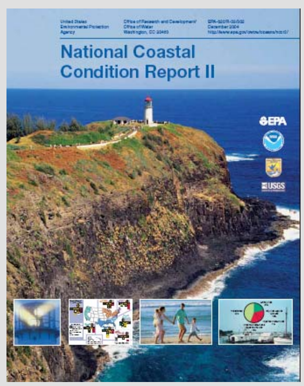
To bridge this information gap, the U.S. Environmental Protection Agency (EPA), the states, tribes, and other federal agencies are collaborating on a new monitoring effort to produce assessments that provide the public with improved water quality information on the nation's waterbodies. This collaboration has produced reports on three national water quality assessments during the past 5 years for coastal and estuarine waters (see Highlight), with similar collaboration planned for other water resource assessments. This 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.

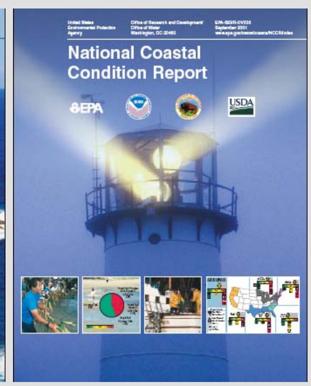
Highlight: National Reports on Coastal Waters

The National Coastal Assessment 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 a *National Coastal Condition Report* (NCCR). The states, EPA, and partner agencies—the National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and the U.S. Fish and Wildlife Service (FWS)—issued the *National Coastal Condition Report II* in January 2005 as the second in this series of environmental surveys of U.S. coastal waters. This report includes evaluations of 100% of the nation's estuaries in the contiguous 48 states and Puerto Rico. Federal, state, and local agencies collected more than 50,000 samples between 1997 and 2000 for the report, using nationally consistent methods and a probability-based design to assess five key indicators of coastal water health. These indicators included water quality, coastal habitat loss, sediment quality, benthic community condition, and fish tissue contaminants.

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 1990–2003 for EPA's National Coastal Assessment. The NEP-CCR also presents recent monitoring data collected and analyzed by each individual NEP for a variety of estuarine quality indicators. The data provided by these NEPs facilitates the development of







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 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, large 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.

Chapter 1 – 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 our bodies, streams and rivers form a network that carries essential water to all parts of the country. 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., Mississippi, Missouri, or Columbia rivers). Most of our nation's waterways are much smaller stream and river systems that form an intimate linkage between land and water.

This 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 this 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 fall into the 1st through 5th order range (Figure 1-1). 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 1storder streams, particularly those located in the western United States, do not flow continuously. These intermittent or ephemeral streams were not included in this WSA because we do not yet have well-developed indicators to assess these waterbodies. At the other end of the range are those 4th and 5th order rivers and streams that are too deep for wadeable sampling methods. These waterbodies will be included in a future survey of non-wadeable rivers.

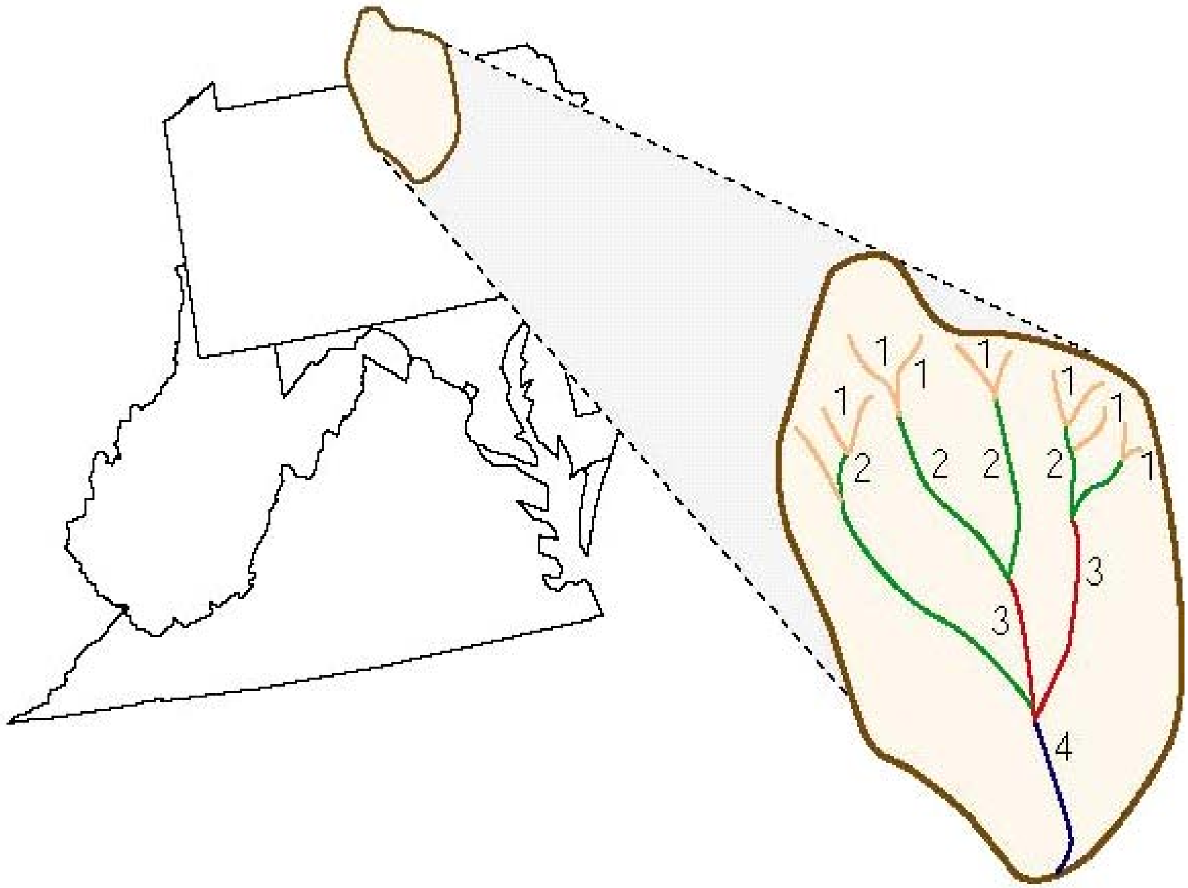


Figure 1-1. Strahler stream order diagram.

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.

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 1storder and 2nd order streams are often quite clear and narrow and are frequently shaded by the grasses, shrubs, and trees that grow along the stream bank. The food base (e.g., leaves and terrestrial insects) for these streams originates from the stream banks. These foods tend to dominate the ecology of these streams, together 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 to 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 only shades 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 these large rivers include insects and algae, larger 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 1-2).

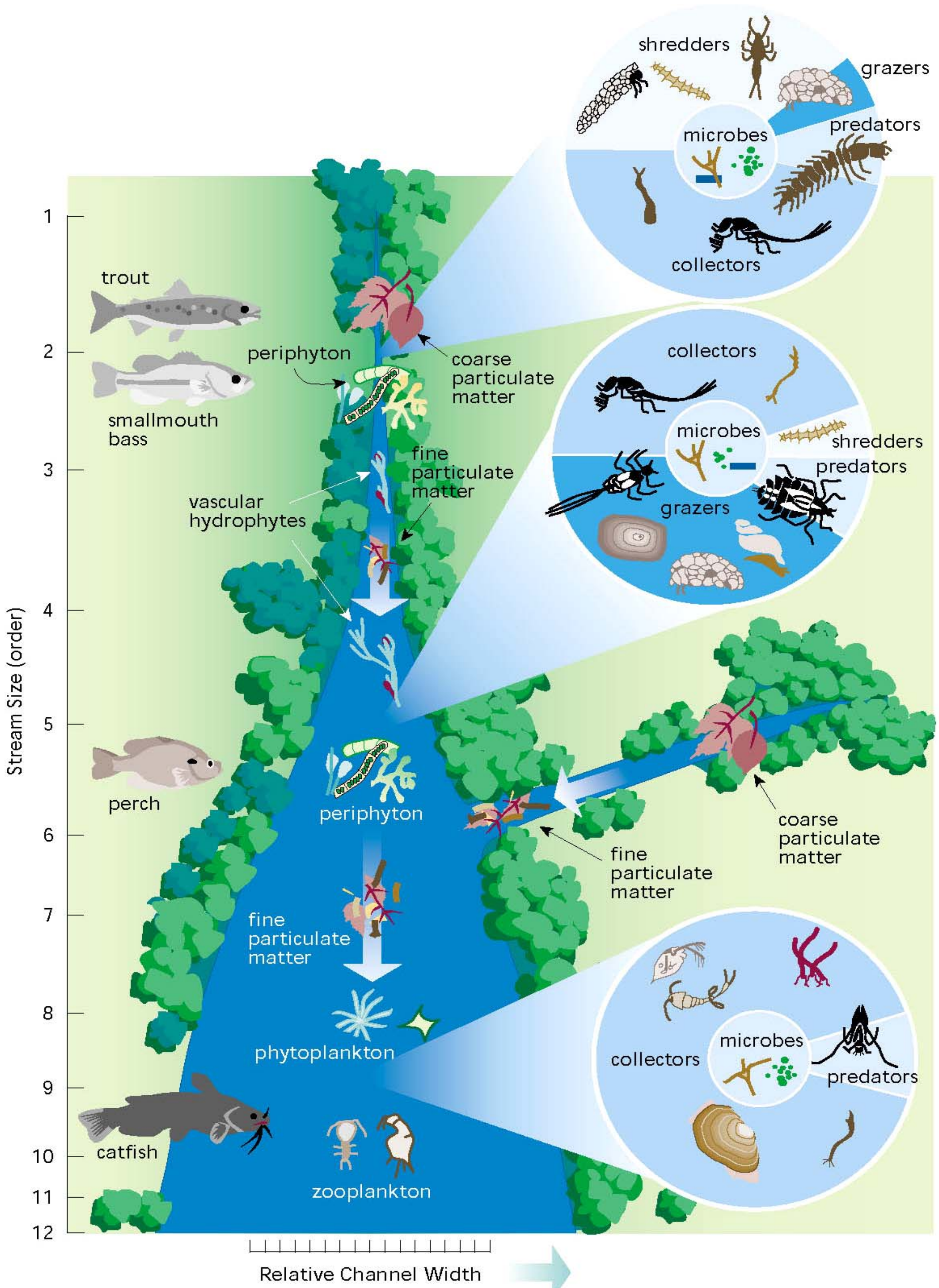


Figure 1-2. Stream characteristics change as the stream's size or stream order increases.

What area does the WSA cover?

This report covers the wadeable streams of the conterminous United States, or lower 48 states (Figure 1-3). This area covers 3,007,436 square miles (mi^2) and includes private, state, tribal, and federal land. Although not included in this WSA, 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 the summer of 2006. 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 will begin stream sampling on the island of Oahu in 2006.

Figure 1-3. Major rivers and streams of the United States.

Major rivers of the United States comprise only 10% of the length of flowing waters. Wadeable streams and rivers make up 90% of the length of the nation's flowing waters.

State political boundaries offer few insights into the true nature of the features that mold our streams and rivers. The most fundamental trait that defines our waters is annual precipitation (Figure 1-4). On either side of the 100th longitude that runs from west Texas through North Dakota, a sharp change occurs where precipitation falls plentifully to the east but sparsely to the west. (The high mountains of the West 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 these waters, but also how we use them, how we value them, and even the legal system with which we manage their allocation. A second divide that defines the nature of our rivers and streams is the north-south gradient in temperature.

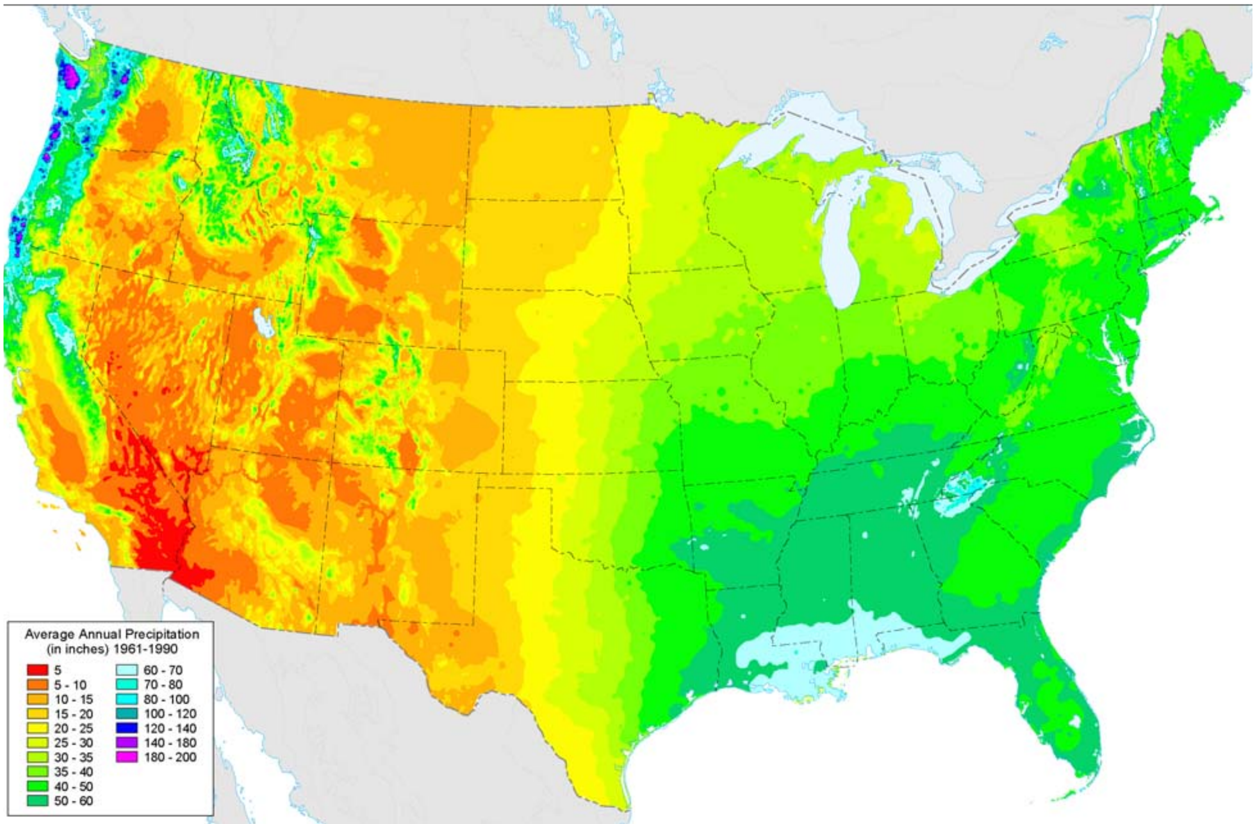


Figure 1-4. Average annual precipitation of the United States.

The 100th meridian runs from Texas north through North Dakota and defines a major gradient of precipitation that defines differences in western and eastern streams.

The nation includes a wide diversity of landscapes, from the maple-beech-birch forests of the east, to the immense agricultural plains and grasslands of the midwest, to the desert and shrubland of the southwest, to the giant mountain ranges of the west (Figure 1-5). 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 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 with its fault-block shoreline stretching 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 land form features that mark the country.

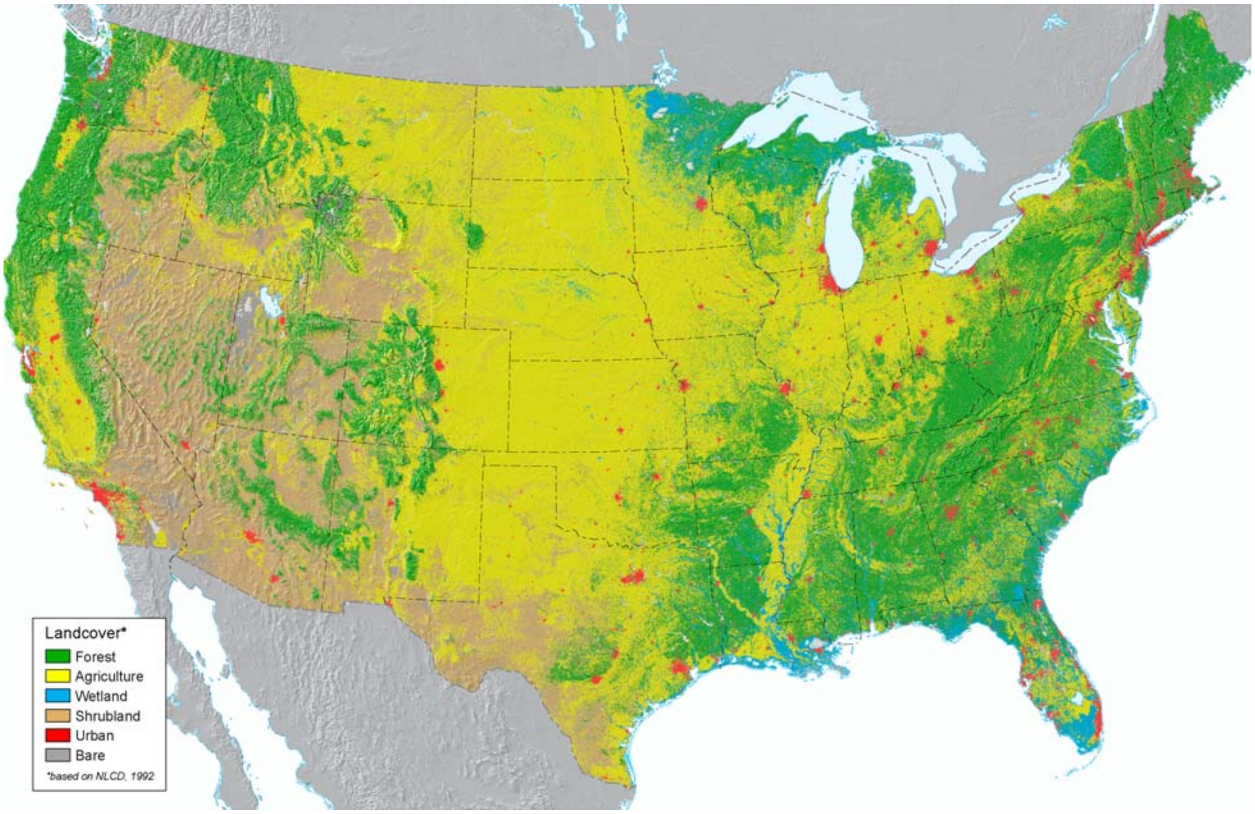


Figure 1-5. The geographic region for WSA and the major landforms and vegetation patterns.

The establishment and spread of European colonies and the Industrial Revolution of the 18th Century intensified the transformation of our natural landscape, as greater numbers of people arrived and modified many of the features of our 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 the 2000 U.S. Census 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 1-6). The current and future condition of the nation's waters will continue to be influenced by our population patterns and how we use all components of a watershed, including surface water, groundwater, and the land itself.

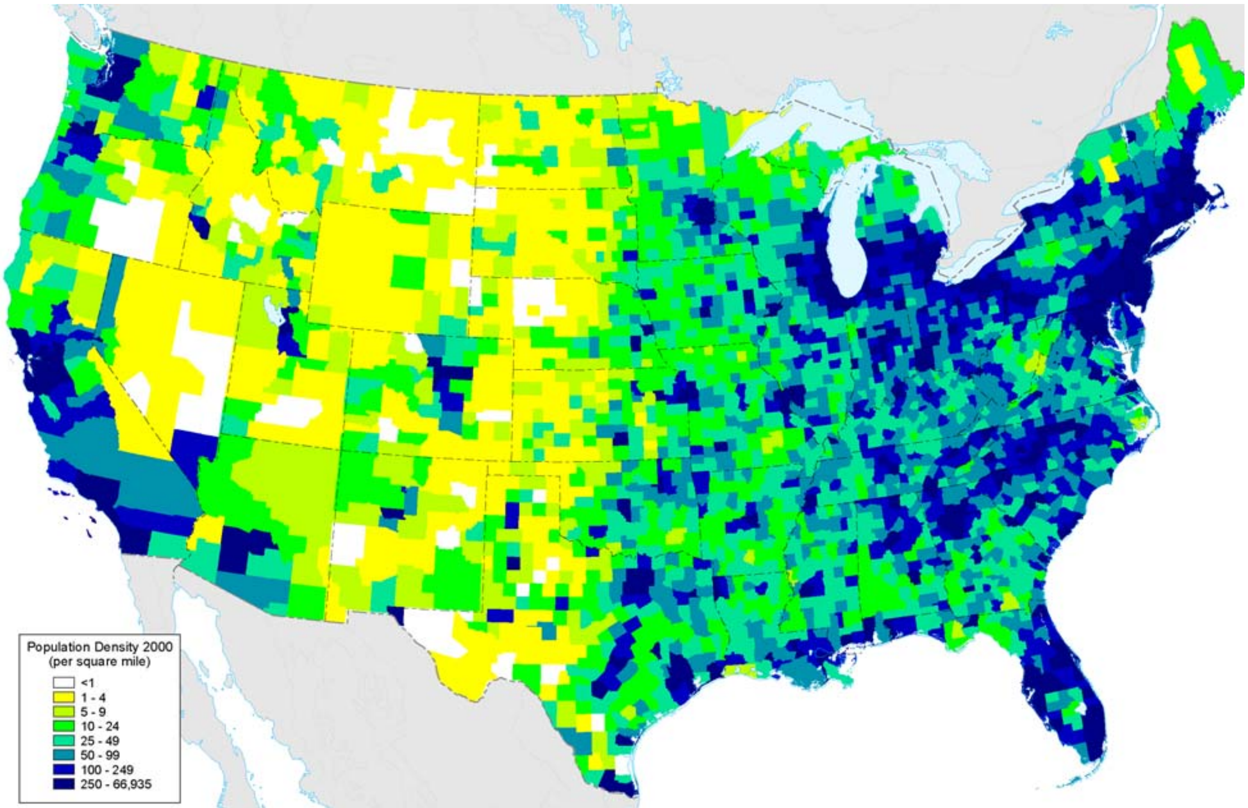


Figure 1-6. Human population density (people per square mile) from the 2000 census.

What regions are used to report WSA results?

The broadest-scale unit for which WSA results are reported is the conterminous United States. For this report, this area has been split into three major regions—the West, the Plains and Lowlands, and the Eastern Highlands—which correspond to the major climate and landform patterns of these areas (Figure 1-7). Chapter 2 of this report describes the results for these broader scale reporting units.

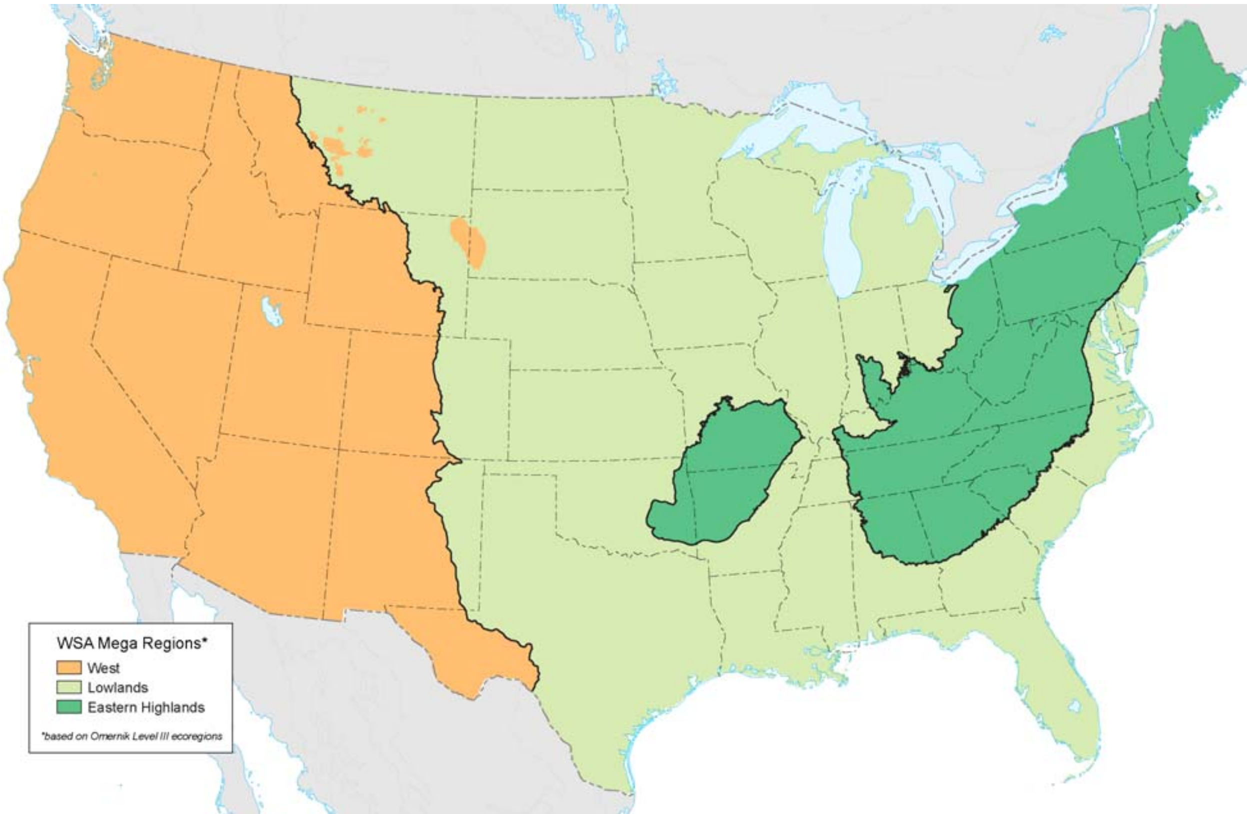


Figure 1-7. Climatic and landform reporting regions for the Wadeable Streams Assessment.

The finest-scale reporting unit included in this WSA consists of nine ecological regions (ecoregions) that further divide the three major regions (Figure 1-8). Ecoregion-specific results are included in Chapter 3 of this report. Some states participating in the WSA opted for an even finer state-scale resolution than the ecoregion scale by sampling additional random sites within their borders. Although these data are included in the analysis described in this report, state-scale results are not presented for each state. The states are preparing similar analyses that reflect their respective water quality standards and regulations.

The Eastern Highlands region is composed of the mountainous areas east of the Mississippi River. It is further divided into two ecoregions: the Northern Appalachians (NAP) ecoregion, which encompasses New England, New York, and northern Pennsylvania, and the Southern Appalachians (SAP) 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.

The Plains and Lowlands region includes five WSA ecoregions: the Coastal Plains (CPL), the Upper Midwest (UMW), the Temperate Plains (TPL), the Northern Plains (NPL) and the Southern Plains (SPL). The Coastal Plains region 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 northward through Memphis, Tennessee. The Upper Midwest reflects a region that is dominated by lakes and has little elevation gradient. The Temperate Plains of the midwest are probably most well-known as the Cornbelt. The Northern and Southern Plains are better known as the Great Prairies, with the Northern Plains ecoregion

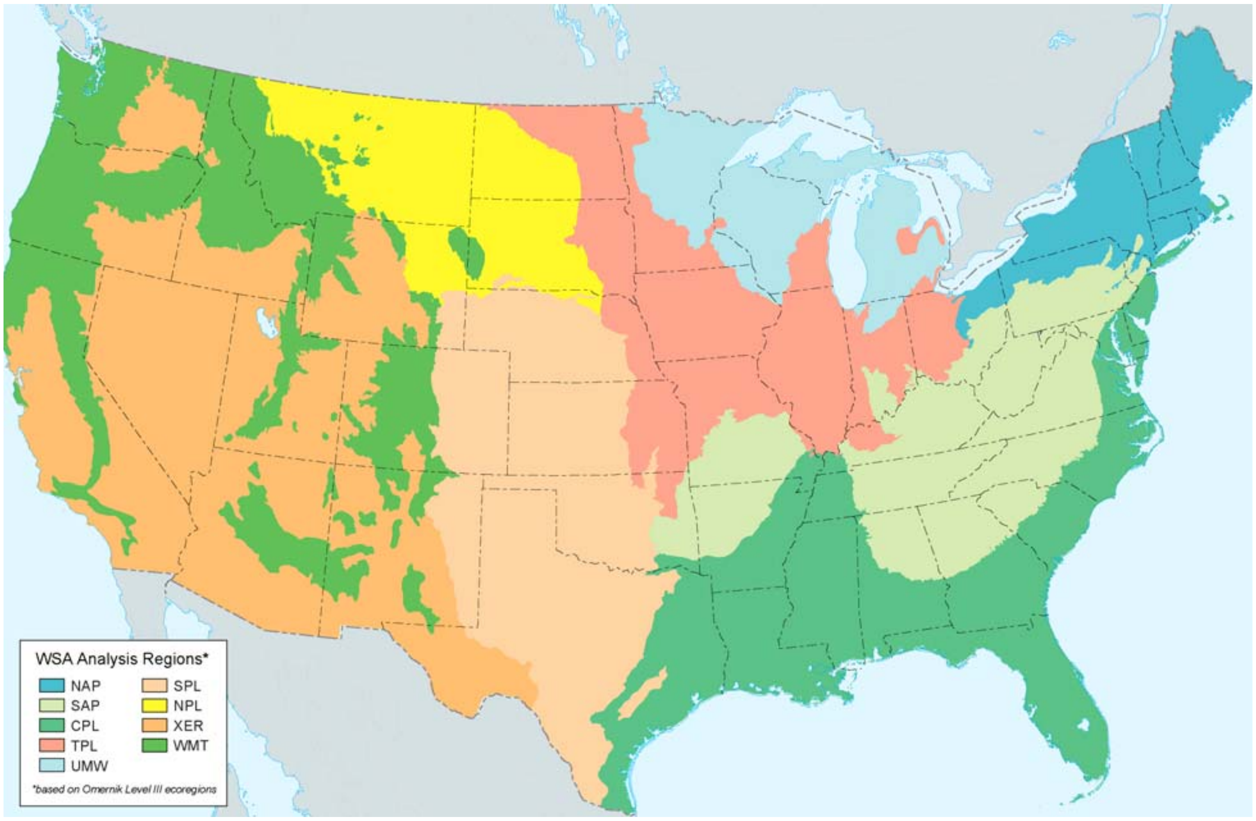


Figure 1-8. Ecological reporting regions for the Wadeable Streams Assessment.

encompassing the Dakotas, Montana, and northeast Wyoming, and the Southern Plains ecoregion encompassing Nebraska, Kansas, Colorado, Oklahoma, and Texas.

The Western region is defined by its Mountainous regions (WMT) and the arid or Xeric region (XER), which includes both the true deserts and the arid lands of the Great Basin.

Landform and climate interact to produce the ecoregions of the United States. Water resources within a particular ecoregion have similar natural characteristics and similar responses 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. The WSA uses ecoregions to report results because the patterns of response to stress, and the stressors themselves, are often best understood in a regional context. The three major regions and the nine ecoregions used in this report are aggregations of smaller ecoregions defined by EPA (Omernik, 1987).

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 analysis, 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 it is unnecessary to obtain a complete census of the resource to reach the desired level of precision for describing its condition.

As consumers of information, we have all become accustomed to seeing survey data 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. Results in the WSA have similar rigor in their ability to estimate the percent of stream miles, within a range of certainty, that are in good condition.

To pick a random sample, one must first know the location of members of the population of interest. The target population for the WSA was the perennial wadeable streams in the 1st through 5th Strahler stream order size classes. The WSA design team used the U.S. Geological Survey (USGS) National Hydrography Dataset (NHD)—a comprehensive set of digital spatial data on surface waters at the 1:100K scale— to identify the location of perennial streams. They also obtained information about stream order from the EPA's River Reach File, a related series of hydrologic databases that provide additional attributes about stream reaches. Using these resources, researchers determined the length of wadeable streams in each of the ecological regions (Figure 1-9).

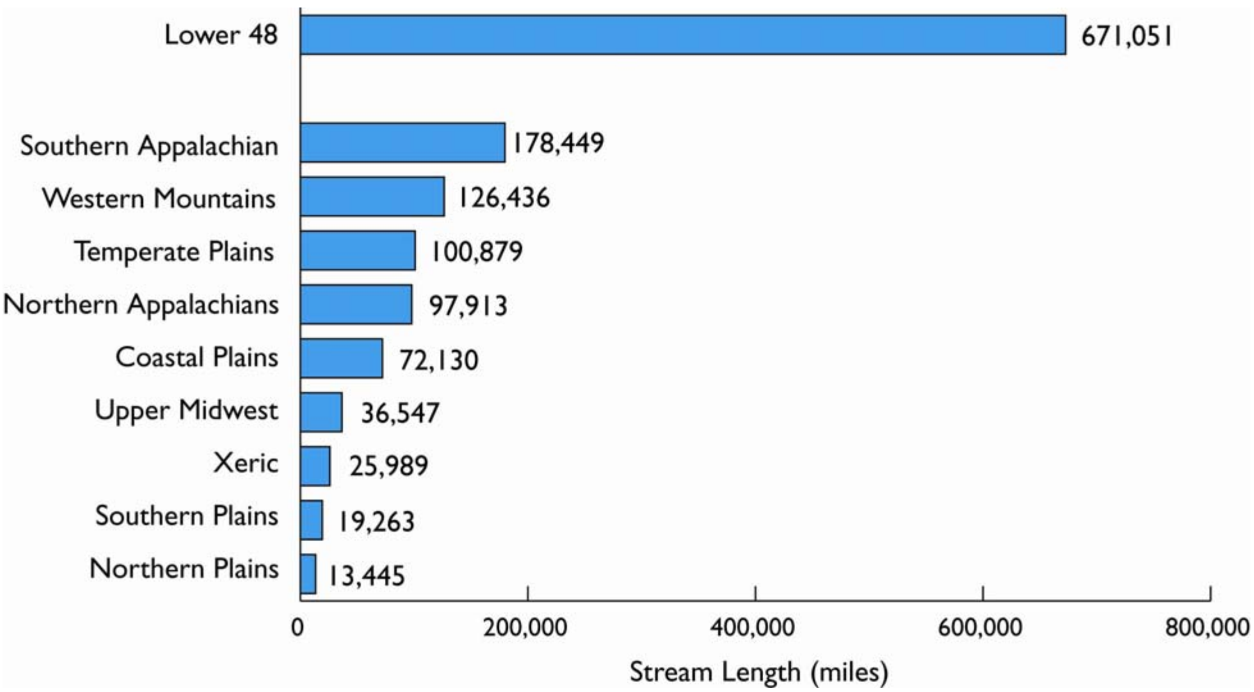


Figure 1-9. Length of wadeable, perennial streams by ecoregion.

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 survey reflected 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 1-10).

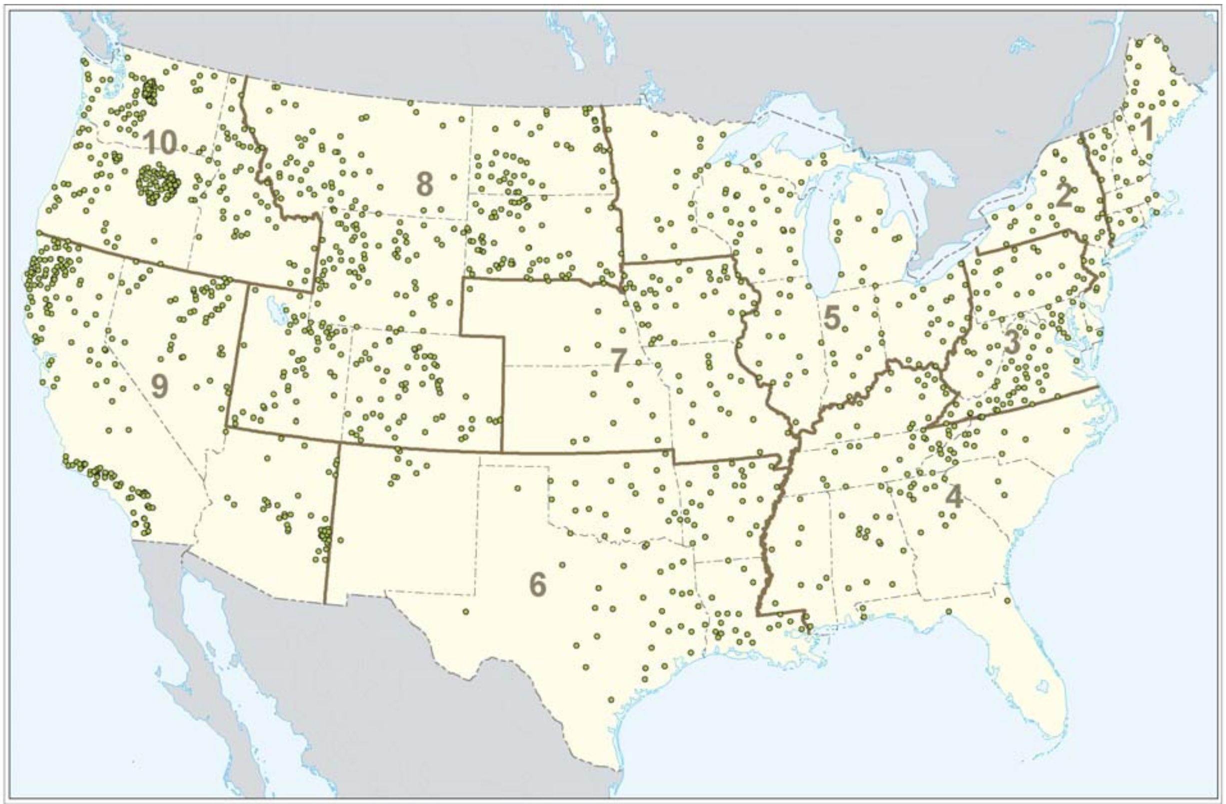


Figure 1-10. Sites sampled for the Wadeable Streams Assessment by EPA Region.

The WSA random sites were allocated by EPA region and by ecological region, based on the distribution of 1st through 5th order streams within those regions. Within each EPA region, the random sites are more densely distributed where the perennial 1st through 5th order streams are more densely located. Sites are more sparsely distributed where streams are sparse. For example, EPA Region 4 includes large portions of the Southern Appalachian and Coastal Plains ecoregions. The random design in EPA Region 4 included greater numbers of sites in the Southern Appalachians because there are more miles of streams there than in the Coastal Plains region (See Figure 1-9).

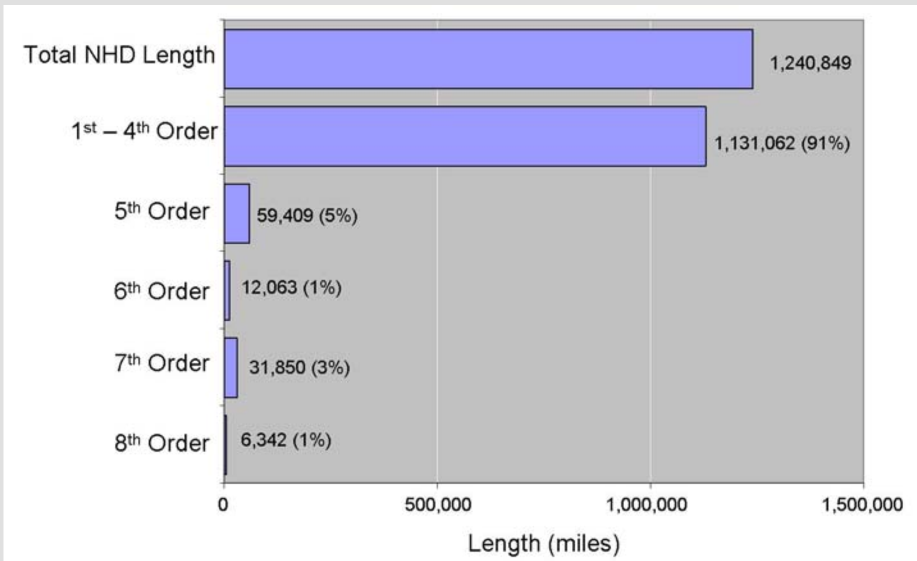
The initial design drew 50 random sites for large-scale ecological regions and EPA regions. An additional 150 reserve replacement sites were generated for each of the EPA regions. These replacement sites were used when site reconnaissance activities documented that one of the original stream sites could not be sampled. Some of the reasons a site was replaced were that the waterbody did not meet the definition of a wadeable stream (e.g., no flowing water over 50% of the reach), was unsafe for sampling, or access was denied by the landowner.

Some of the unusually dense site patterns visible on Figure 1-10 occur because states opted to increase the intensity of random sampling to characterize statewide conditions or specific areas of interest. For example, 15 states increased the number of random sites to support state scale characterizations of stream condition. Additional areas of intensification were added in Washington, Oregon, and California (seen by dense clusters). When sites from an area of intensification are used in the broader scale assessment for a large ecoregion, the weights associated with those sites are adjusted so that those sites do not dominate the ecoregion results.

The survey design and analysis assured that ecological variability present in all wadeable streams and rivers is represented in the assessments.

Highlight: Wadeable Streams Assessment Sampling Frame

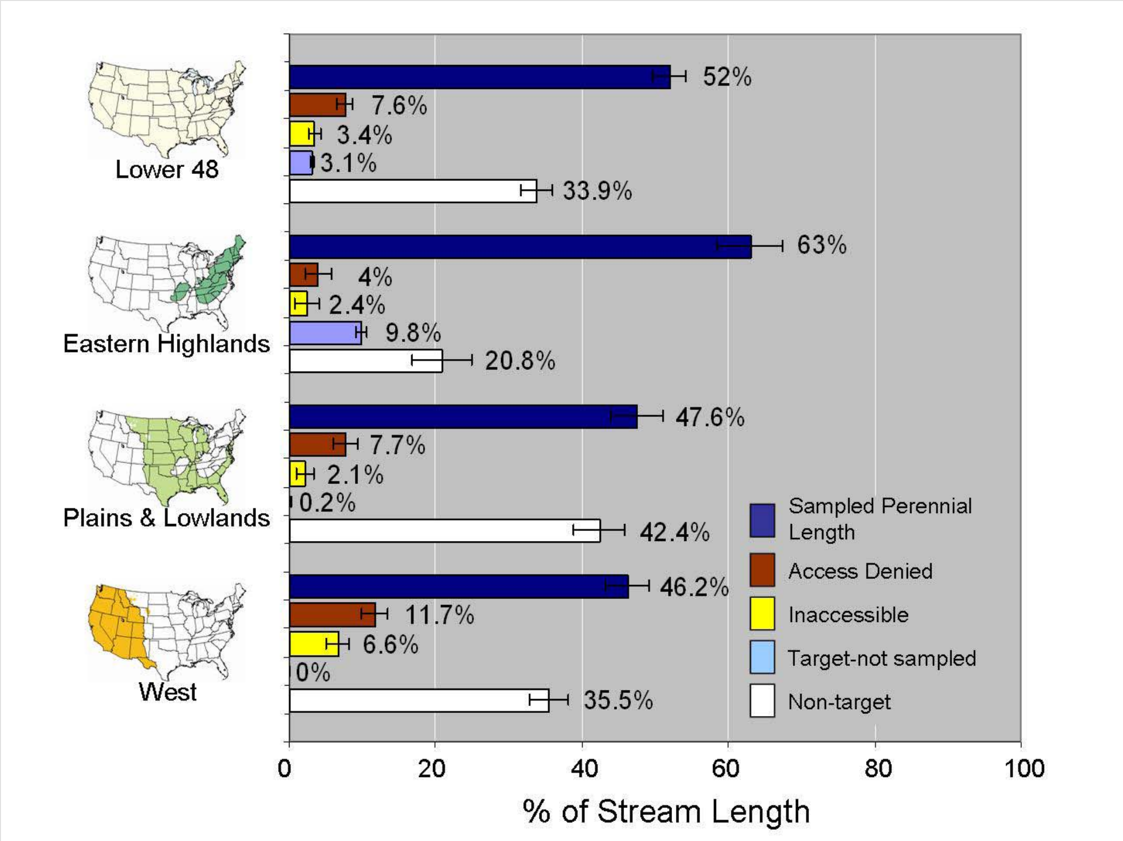
perennial stream network contained in the USGS-EPA National Hydrography Dataset (NHD). NHD is a digitized version of 1:100K USGS topographic maps, showing both perennial and non-perennial streams. The total length of the NHD stream and river network labeled perennial in the conterminous United States is 1,204,859 miles. Of this amount, 1,131,062 miles are in 1st through 4th order streams, which make up 91% of the total length of flowing waters, as shown in the following figure. The 1st through 5th order streams are those most likely to be wadeable and form the basis for the target population in WSA.



Estimate of perennial length of streams and rivers from NHD 1st through 4th order streams comprise 91% of total estimated length in the NHD. The 1st through 5th order systems form the basis for the sampling design frame for the WSA.

When sites were selected for sampling in WSA, an office and field reconnaissance was conducted to determine if the streams labeled as perennial in NHD were actually flowing during the sampling season; if they weren't, they would be considered non-perennial, dropped from the sampling effort, and replaced with perennial streams. Other factors were also a basis for not sampling the original selected sites, including field crews being denied permission for access to the site by the landowner; physical barriers to sampling (i.e., inaccessible); or safety concerns for the crews. The decisions on whether a site was non-perennial or inaccessible was determined either in the initial office evaluation, preliminary field evaluation, or by the field crew sent to sample the site. The benefit of conducting a statistically based survey is that, when all of this information is collected and tracked, the results can be applied to the entire population of streams of interest and the total size of each category can be estimated. The results can also be fed back into the NHD so that the system can update the status of the perennial/non-perennial streams information.

(continued)



Results of office and field evaluations for the 1st through 4th orders streams in NHD. Percentages represent the percent of the NHD estimates of length that fall into each of the categories.

Of the more than 1 million miles of estimated perennial length, almost 400,000 miles (34%) were found to be non-perennial or non-target in some other way (e.g., wetlands, reservoirs, irrigation canals). The remaining target stream length (780,519 miles) represents the portion of NHD that meets criteria for inclusion in the WSA (perennial, wadeable streams). A portion of the stream length (89,894 miles or 12%) was not accessible to sample because crews were denied access by landowners. An additional portion of the target stream length (40,677 miles or 5%) was physically inaccessible due to physical barriers or other unsafe local conditions.

How were waters assessed?

Each 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 the 1,392 random stream sites using standardized field protocols. The field protocols were designed to consistently collect data relevant to the ecological 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 1-11). Field crews sent water samples to a laboratory for basic chemical analysis; biological samples, collected from 11 transects along each stream reach, were sent to taxonomists for identification of macroinvertebrates. Crews also completed roughly

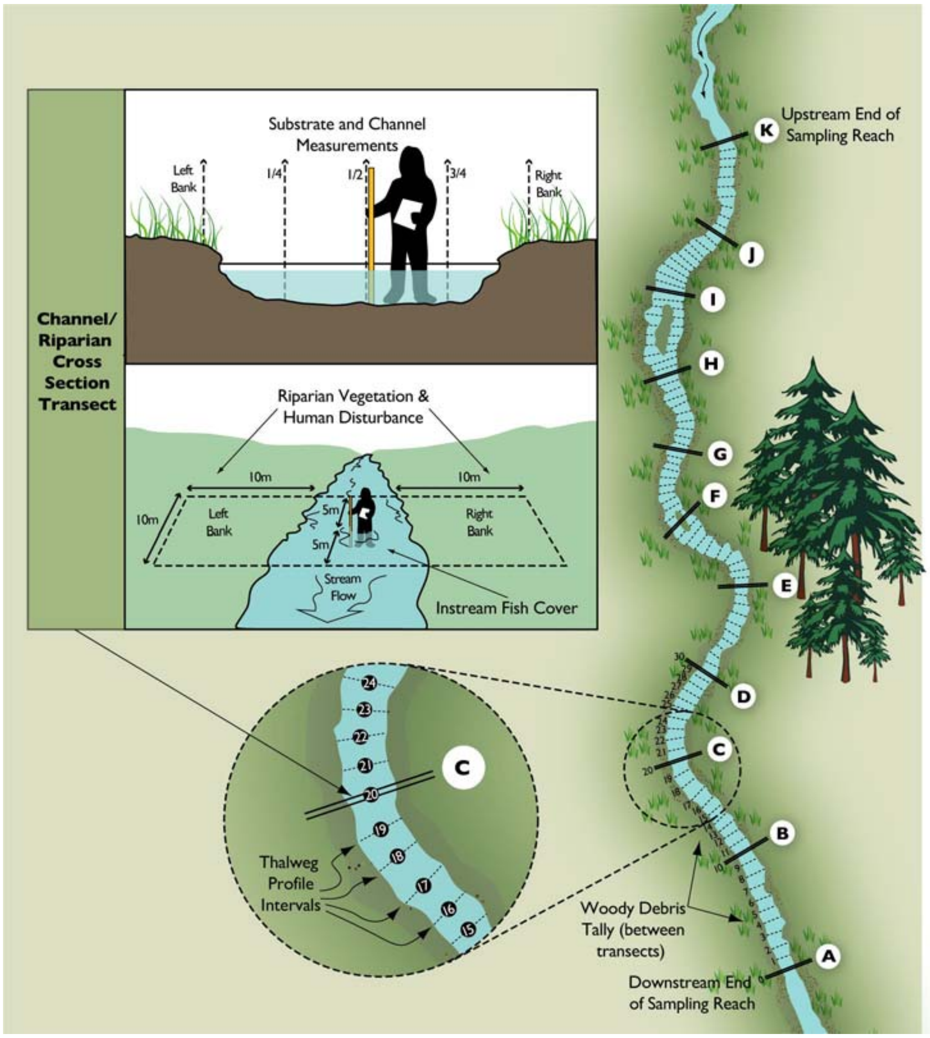


Figure 1-11. Reach layout for sampling.

35 pages of field forms, recording data and information about the physical characteristics 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 wide range of methods to sample streams, inconsistent results might have arisen from their use in this survey. Standardization allows the data to be combined to produce a nationally-consistent assessment. In fact, 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 report that examines the comparability of methods and explores options for how data may be used together will be completed later in 2006.

The WSA uses benthic macroinvertebrates as the biological indicator of ecological condition. Benthic macroinvertebrates (e.g., aquatic larval stages of insects, such as dragonfly larvae and aquatic beetles; crustaceans such as crayfish; worms; and mollusks) live throughout the stream bed attached to rocks and woody debris and burrowed in sandy stream bottoms and among the debris, roots, and grasses that collect and grow along the water's edge (Figure 1-12). The 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 acroinvertebrates 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.

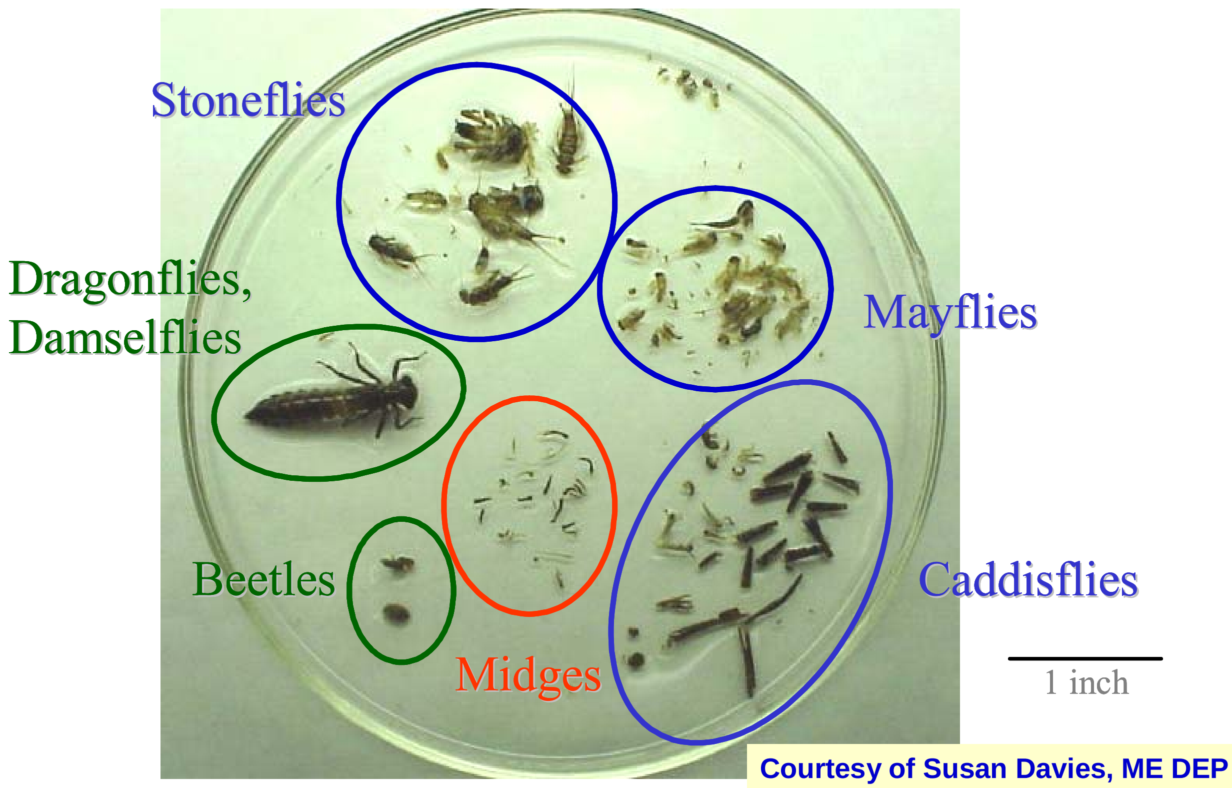


Figure 1-12. Stream macroinvertebrates.

Macroinvertebrates in streams serve as the basis for the indicators of condition for the WSA.

Macroinvertebrates give us 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.

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 the current conditions, but also the stresses and changes in conditions over time and the cumulative impacts.

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.

Data on biological condition are invaluable for managing our aquatic resources and ecosystems. We can use it to set protection and restoration goals, to decide what to monitor and how to interpret what is found, to identify stresses to the waterbody and decide how they should be controlled, and to 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 their 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.

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; 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.

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 of these stressors are naturally occurring, and some result only from human activities, but 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 mining. Biological stressors are characteristics of the biota that can influence biological integrity, such as 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 stressors 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 additional stressors.

One of the key components of an ecological assessment is a measure of how important (e.g., how common) each stressor is in 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.

Setting Expectations

In order to interpret the data collected and to assess current ecological condition, chemical, physical, and biological measurements must be comparable to a benchmark or estimate of what we 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? Should we accept that some level of anthropogenic disturbance is a given 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 waters? Because of the difficulty of estimating historical conditions for many of our indicators, WSA uses "least-disturbed condition" as the reference condition, which means that the condition represents the best available chemical, physical, and biological habitat conditions given the current state of the landscape. Least-disturbed condition is determined by evaluating data collected at sites selected according to a set of explicit screening thresholds used to define what is in good condition (or least disturbed by human activities). To reflect the natural variability across the American landscape, these thresholds vary from region to region.

The WSA's screening thresholds were developed with the goal of identifying the least amount of ambient human disturbance in each of the nine ecoregions. The WSA uses physical and chemical data collected at each site (e.g., riparian condition, nutrients, chloride, turbidity, excess fine sediments) to determine whether any given site is in least-disturbed condition for its ecoregion. Data on land use in the watersheds is not used for this purpose; for example, sites in agricultural areas may be considered least disturbed, provided they exhibit chemical and physical conditions that are among the best for their region. The WSA also does not use data on biological assemblages to select reference sites; these assemblages are the primary components of the ecosystems for which we need estimates of least-disturbed condition, so to use them would constitute circular reasoning.

For each of the stressor indicators, the WSA used a similar process (i.e., identifying least-disturbed sites according to specific criteria, but excluding the specific stressors themselves from the criteria identifying the sites).

This reference-site approach is used to set expectations and benchmarks for interpreting the data on stream condition. The range of conditions found in the reference sites for an ecoregion describes a distribution of those biological or stressor values expected for the least-disturbed condition. The benchmarks used to define distinct condition classes (e.g., good, fair, poor) are drawn from this reference distribution. At a national meeting to discuss data analysis options, the 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.

The WSA's approach examined the range of values for a biological or stressor indicator 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 miles in the poor category were worse than the best 95% of the least-disturbed sites used to define reference condition. Similarly, the 25th percentile of the reference distribution was used to distinguish between fair sites and those in good condition. This means that stream miles reported as being in good condition were as good as or better than the best 75% of the least-disturbed sites used to define reference condition.

Within the reference site population, there exist two sources of variability: natural variability and variability due to human activities. The wide range of habitat types naturally found within each ecoregion creates a spread of reference sites representing these differing habitats. Capturing this natural diversity 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 are changes resulting from human activites. Many areas in the U.S. have been altered, and their natural landscapes transformed with 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. These can be streams in the mountains or in areas with very low population densities. Other regions of the country have few sites that have not been influenced by human activities. Within these regions, the least-disturbed reference sites displayed more variability in quality than areas where the least-disturbed reference sites were in watersheds with little human disturbance.

Variation within the reference distribution due to disturbance was addressed before setting benchmarks 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 of the reference sites. Additional details on how least-disturbed condition and benchmarks for the condition categories were set for the WSA can be found in Appendix A at the back of this report.

Chapter 2 – 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." This report examines these three aspects of water quality through a small set of commonly used and widely accepted indicators. Although this 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 climatic and landform 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) found in streams. The WSA focused on just one assemblage, benthic macroinvertebrates (e.g., aquatic insects, crustaceans, worms and mollusks). 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-fisherman know, the insects emerging from streams and rivers are good indicators of the quality of waters and 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 measures of biological condition: the Macroinvertebrate Index of Biotic Condition and the Observed/Expected (O/E) Ratio of Taxa Loss.

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 our waters: plants, including algae; macroinvertebrates; and vertebrates such as fish. The purpose of examining multiple biological assemblages rather than only one is to generate a broader perspective of the condition of the aquatic resource of interest.

Each assemblage plays a different role in the way rivers and streams function. Algae and macroinvertebrates occur throughout all types and sizes of streams, while very small streams may be naturally devoid of fish. Algae are the base of the food chain and capture light and nutrients to create life. They are sensitive to changes in shading, turbidity, and increases or decreases in nutrients. Macroinvertebrates feed both on algae and on other organic material that enter the aquatic system from the surrounding watershed. Macroinvertebrates also form the base of the food chain for many, though not all, aquatic vertebrates. Fish are an important food source for people and wildlife, and are themselves generally dependent on macroinvertebrates for food. 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 (EMAP West) before it was expanded to include the rest of the United States. This 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.

Macroinvertebrate Index of Biotic Condition

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 aspects of the biota that reflect "naturalness." Originally developed as an Index of Biotic Integrity for fish in Midwestern streams, the Index of Biotic Condition has been modified and applied to other regions, taxonomic groups, and ecosystems.

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 the pollution-sensitive insect groups, indicate a variety of physical habitats and food sources and an environment exposed to generally lower levels of stress.

- **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 abundances 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 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:** A taxon's feeding strategy is captured in the feeding metrics. 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 feeding groups will change. For example, as a stream loses its canopy (a source of leaves and shading), the aquatic community will shift 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. If, for example, 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.

What are taxa?

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

The specific metrics chosen for each of these categories varied among the nine ecoregions used in the analysis (see Appendix A). 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 length of stream in a region, and nationally, with a given Macroinvertebrate Index score.

Findings for the Macroinvertebrate Index

As illustrated in Figure 2-1, 42% of the nation's stream length is in poor condition, and 25% is in fair condition compared to the least-disturbed reference condition in each of the nine WSA ecoregions. The 28% of stream miles rated good have conditions most similar to the reference distribution derived from the best available sites in each ecoregion. The 5% of unassessed stream length results from the fact that 1st order streams in New England were not sampled for the WSA.

Macroinvertebrate Index of Biotic Condition

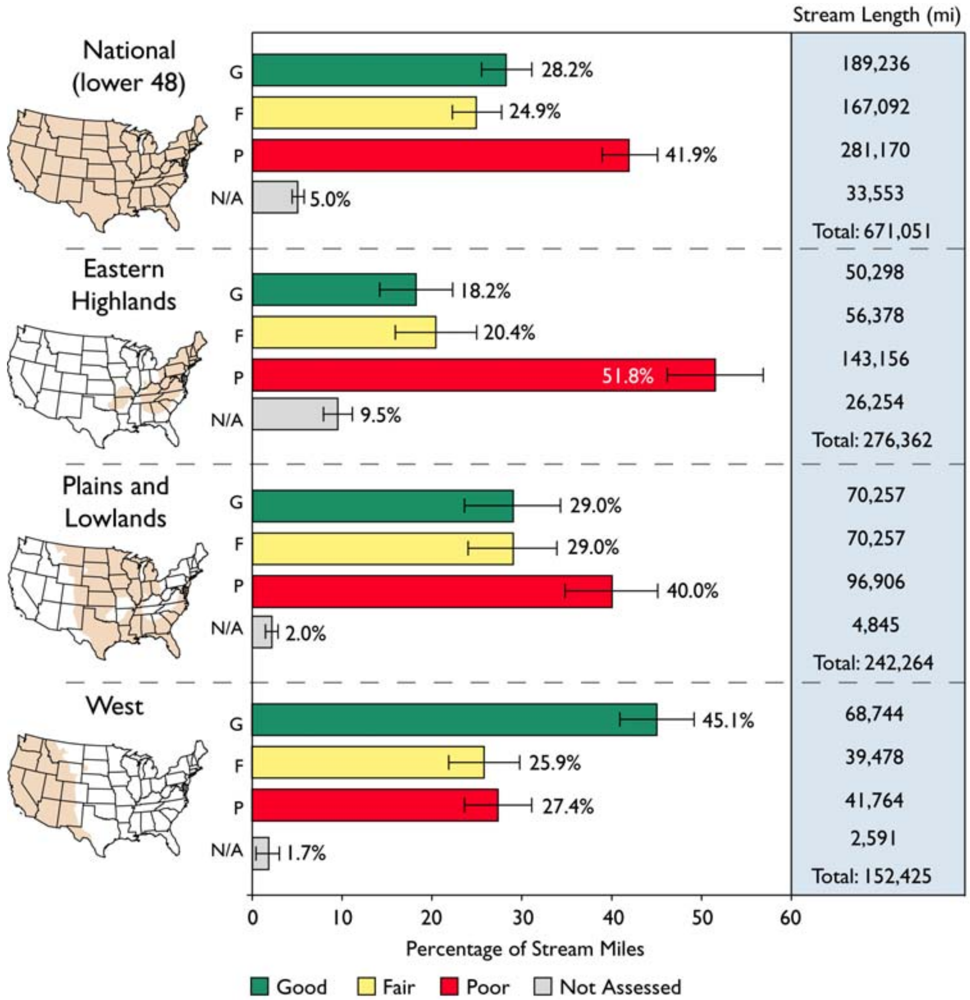


Figure 2-1. Biological condition of streams based on Macroinvertebrate Index of Biotic Condition.

The benthic 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 ecological regions based on the condition at the best available regional reference sites. Stream resources in good condition are most similar to least-disturbed reference condition. The intermediate category, fair, has Macroinvertebrate Index scores worse than 75% of reference. The poor streams have Macroinvertebrate Index scores worse than 95% of reference.

The Eastern Highlands region has the largest proportion of streams (52%) in poor condition for macroinvertebrate integrity, followed by the Plains and Lowlands (40%) and the West (27%). Chapter 3 provides the results for each of the 9 WSA ecoregions.

What are confidence intervals?

Confidence intervals (i.e., the small lines at the end of the bars in the report's charts) are provided to convey some sense of the certainty or confidence that can be placed in the information presented in this document. For example, for the national macroinvertebrate index of biotic condition, the WSA finds that 28.2% of the stream length is in good condition and our confidence is +/- 2.8%, which generally means that we are 95% sure that the real value is between 25.4% and 31%. The confidence interval depends primarily on the number of sites that were sampled. In general terms, as more streams are sampled, the confidence interval becomes narrower, meaning there is more confidence in the findings. When fewer streams are visited, the confidence intervals become broader, meaning there is less certainty in the findings. This pattern can be seen in Figure 2-1, in which the confidence interval for the national results (the largest sample size) is narrowest; in the climatic regions and ecoregions, on the other hand, smaller numbers of streams were sampled and the confidence intervals are generally broader. Ultimately the breadth of the confidence interval will be a trade off 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 O/E measure looks at 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 reference sites. The model thus 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, we can quantify the proportion of expected taxa that have been lost as the ratio of O/E. Originally developed for streams in the United Kingdom, models are modified for the specific natural conditions in each area for which it is used. The O/E is currently used by several countries and numerous states in the United States.

O/E values range from 0 (none of the expected taxa are present) to slightly greater than 1 (more taxa are present than expected). O/E 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 the site; thus, an O/E score of 0.9 indicates that 90% of the expected taxa are present and 10% are missing. O/E values must be interpreted in 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. Regions with lower-quality reference sites will have a lower bar. Although an O/E 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 models to predict the extent of taxa loss across streams of the United States: one for the Eastern Highlands, one for the Plains and Lowlands, and one for the West. Analysts used the O/E scores observed at each site to generate estimates of the lengths of stream in the U.S. estimated to fall into four categories of taxa loss.

Although in many cases the results of the O/E Taxa Loss analysis are similar to the results of the Macroinvertebrate Index, such agreement will not always occur. The O/E 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 2-2 displays the national and regional taxa loss summary for the nation's stream resource. These data are presented in four categories: (1) less than 10% taxa loss, (2) 10 – 20% taxa loss, (3) 20 – 50% taxa loss, (4) and more than 50% taxa loss. Across the country, 42% of the stream miles have lost less than 10% of the expected taxa, which means they have retained more than 90% of their taxa; 13% have lost 10 – 20%; 26% have lost 20 – 50% of the expected taxa; and 13% of the stream miles have lost more than 50% of the expected taxa. Within the three major regions, the Eastern Highlands has experienced the greatest loss of expected taxa, with 17% of the stream length having experienced a loss of 50% or more. An additional 29% has lost 20 – 50% of the expected taxa; 13% have lost 10 – 20%; and only 28% of streams have lost fewer than 10% of the expected taxa.

O/E Taxa Loss

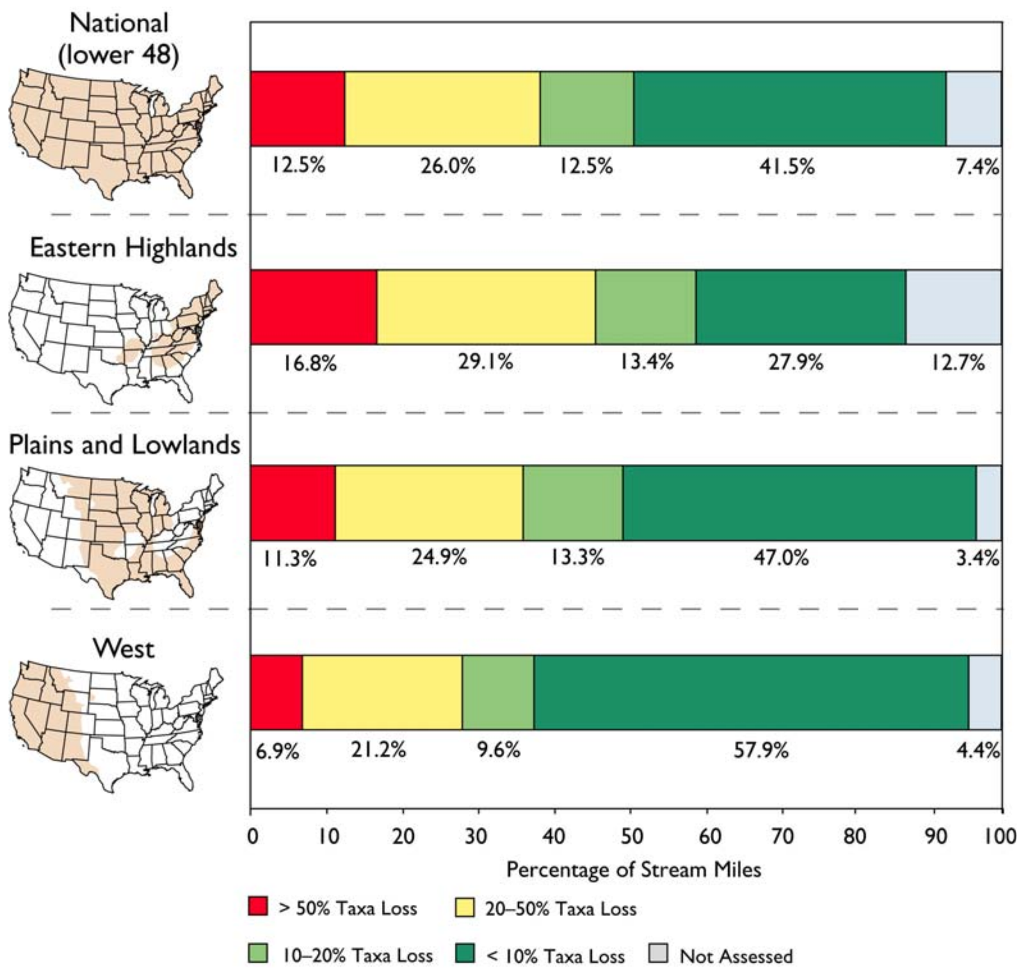


Figure 2-2. Macroinvertebrate taxa loss as measured by the Observed/Expected (O/E) Ratio.

The O/E predictive model 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.

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. In this WSA, we have selected a short list of stressors from each of these categories. This list is not intended to be all-inclusive, and in fact, some important stressors are not included because there is no current 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 stressor 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. Although any form of human land use can be a source of one or more stressors to streams, the WSA chose to focus only on the stressors, rather than on their sources.

The summary results for indicators of chemical and physical habitat are shown in Figures 2-3 through 2-10. Results for each of the nine WSA ecoregions are presented in Chapter 3 of this report.

Chemical Stressors

Four chemical stressors were assessed 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 1.5 (*Setting Expectations*). The results for each ecoregion were tallied to report on conditions for the three major regions and the entire nation. See Appendix A for more details on the development of regional thresholds for all indicators.

Highlight: Nutrients and Eutrophication in Streams

Eutrophication is a condition characterized by excessive plant growth that results from too many nutrients in a waterbody. Eutrophication is a natural process, but human activities can accelerate it 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 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, and 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 1) negative impacts on aquatic life (the focus of the WSA); 2) adverse health effects on humans and domestic animals; 3) aesthetic and recreational use impairment; and 4) 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 our 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 has also been demonstrated to affect stream animal communities (see references 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 grow poorly 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 water-quality symptoms—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.

Total Phosphorus Concentration

Phosphorus is usually considered the most likely nutrient limiting algal growth in U.S. freshwater waterbodies. Because of the naturally low levels of phosphorus in stream systems, even small increases in phosphorus levels can impact a stream's water quality. Some areas of the country have naturally higher levels of phosphorus, such as streams originating from groundwater in volcanic areas like eastern Oregon and Idaho. 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 9 WSA ecoregions.

Phosphorus influx leads to increased algal growth, which reduces dissolved oxygen levels and water clarity within the stream. (See the Highlight on nutrients and eutrophication for more information about the impacts of excess phosphorus and nitrogen.) Phosphorus is a common component of fertilizers, and high 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 stream length nationwide has high levels of phosphorus, 16% has medium levels, and 49% has low levels (Figure 2-3). Of the three climatic and landform regions, the Eastern Highlands has the greatest proportion of stream miles with high levels of phosphorus (43%), followed by the Plains and Lowlands (25%) and the West (19%).

Total Nitrogen Concentration

Nitrogen, another nutrient, is particularly important as a contributor to coastal and estuarine algal blooms. Nitrogen is the primary limiting nutrient in many 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 on nutrients and eutrophication). Common sources of nitrogen include fertilizers, wastewater, animal wastes, and atmospheric deposition.

Total Phosphorus

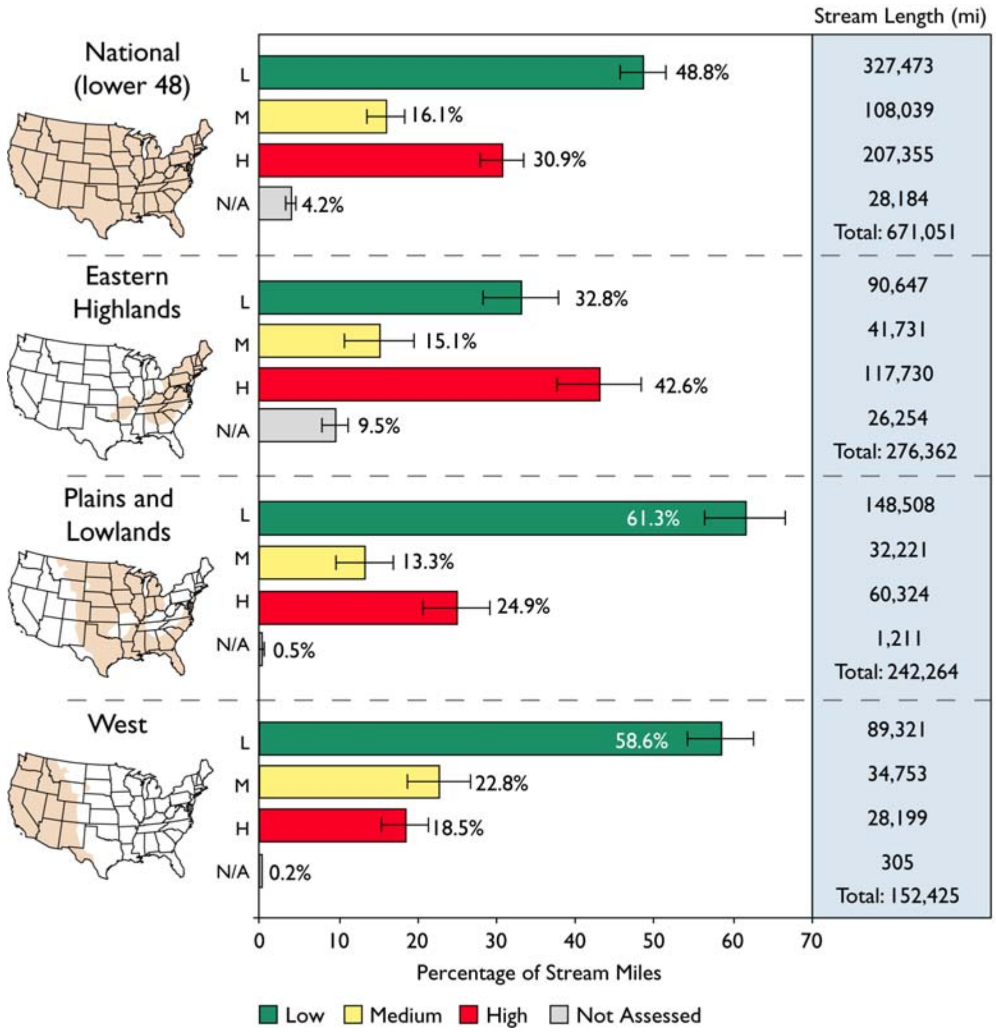


Figure 2-3. Total phosphorus concentrations in U.S. streams.

This is the percent of stream miles with low, medium, and high levels of phosphorus based on regionally relevant thresholds derived from the best quality regional reference sites. Low concentrations are most similar to reference condition. Medium concentrations are higher than the 75th percentile of reference condition. High concentrations are higher than the 95th percentile.

Findings for Total Nitrogen

A significant portion of stream miles (32%) have high levels of nitrogen compared to least-disturbed reference conditions. Another 21% have medium levels, and 43% of stream miles have relatively low levels (Figure 2-4). As with phosphorus, the Eastern Highlands region has the highest proportion of stream length with high levels of nitrogen (42%), followed by the Plains and Lowlands (27%) and the West (21%).

Total Nitrogen

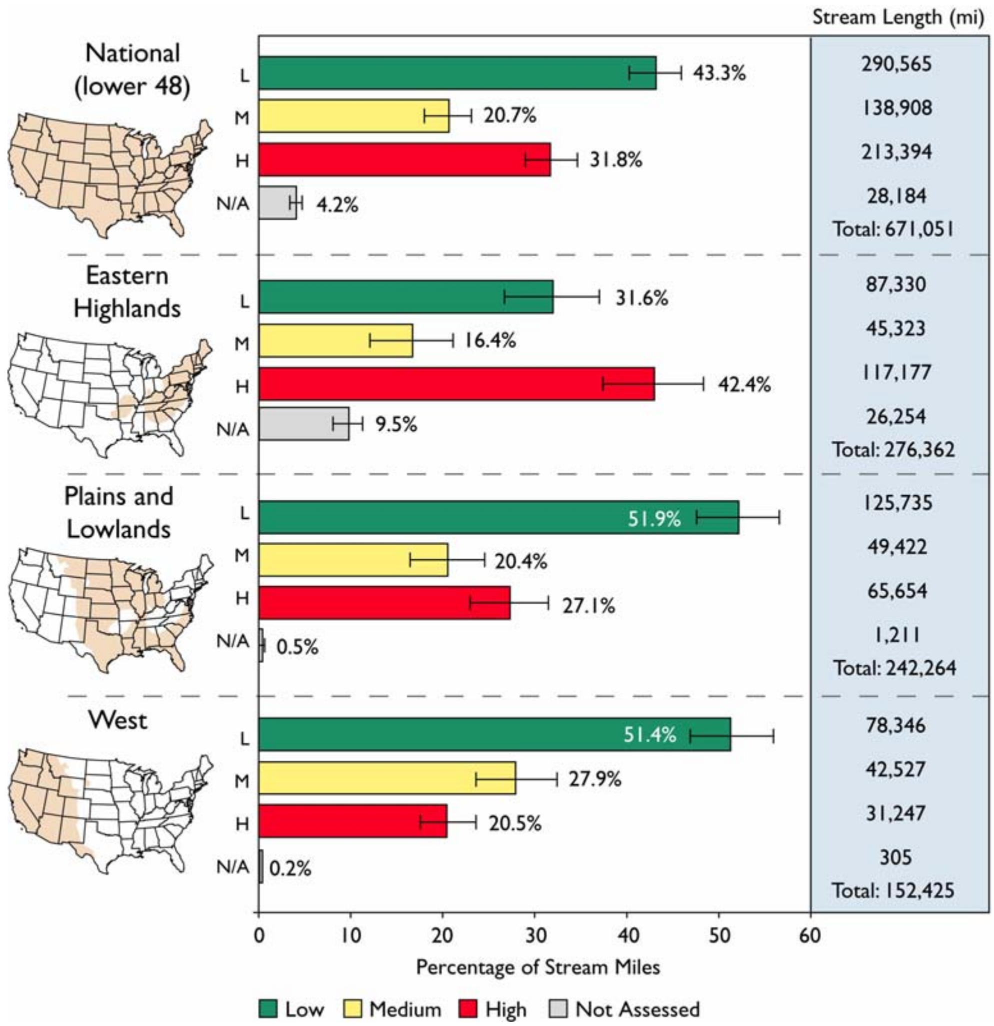


Figure 2-4. Total nitrogen concentrations in U.S. streams.

This is the percent of stream miles with low, medium, and high levels of nitrogen based on regionally relevant thresholds derived from the best-quality regional reference sites. Low concentrations were most similar to reference condition. Medium concentrations were higher than the 75th percentile of reference condition. High concentrations were defined as higher than the 95th percentile.

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 stream length nationwide has high levels of salinity, 10% has medium levels, and 83% has low levels compared to the levels found in least-disturbed reference sites for the 9 WSA ecoregions (Figure 2-5). The Plains and Lowlands region has the highest proportion of stream length with high levels of salinity (5%), followed by the West (3%). In the Eastern Highlands, high levels of salinity are found in about 1% of stream length.

Salinity

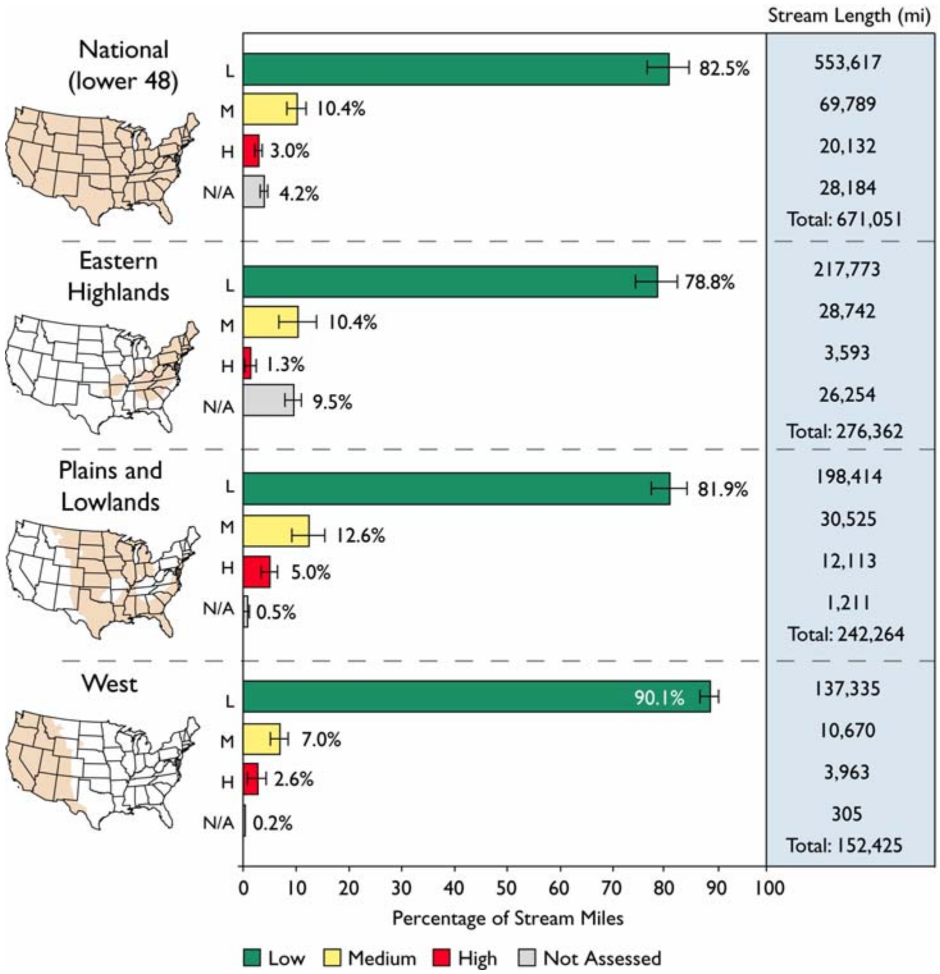


Figure 2-5. Salinity conditions in U.S. streams.

This indicator is based on electrical conductivity measured in water samples. Thresholds are based on conditions at regional reference sites.

Acidification

Streams and rivers can become acidic through the effects of acid deposition (e.g., acid rain) or 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 such natural sources as high dissolved organic compounds. For the WSA assessment, we have chosen to identify 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, whether chronic or episodic, and streams that are acidic because of mine drainage.

Acid rain forms when smokestack and automobile emissions (particularly sulfur dioxide and nitrogen oxides) combine with moisture in the air, forming 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 or ANC. When ANC values fall below zero, the water is considered acidic and can be either directly or indirectly toxic to biota (e.g., 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.

Acid mine drainage forms when water moves through mines and mine tailings, combining with sulfur-bearing minerals to form strong solutions of sulfuric acid and mobilizing many toxic metals. As in the case of acid rain, the acidity of waters in mining areas can be assessed by using their 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 and sulfate are low, acidity can be attributed to acid rain. When ANC is low and sulfate is high, acidity can be attributed to acid mine drainage. Mine drainage itself, even if not acidic, can cause harm to aquatic life. The WSA does not include an assessment of the extent of mine drainage that is not acidic.

Findings for Acidification

Figure 2-6 shows that nationally, about 2% of the stream length is impacted by acidification from anthropogenic sources. This includes acid deposition (0.7%), acid mine drainage (0.4%), and stream miles likely to be episodically acidic during high runoff events (1%). Although these numbers appear relatively small, they reflect a significant impact in certain parts of the United States (particularly in the Eastern Highlands region).

Acidification

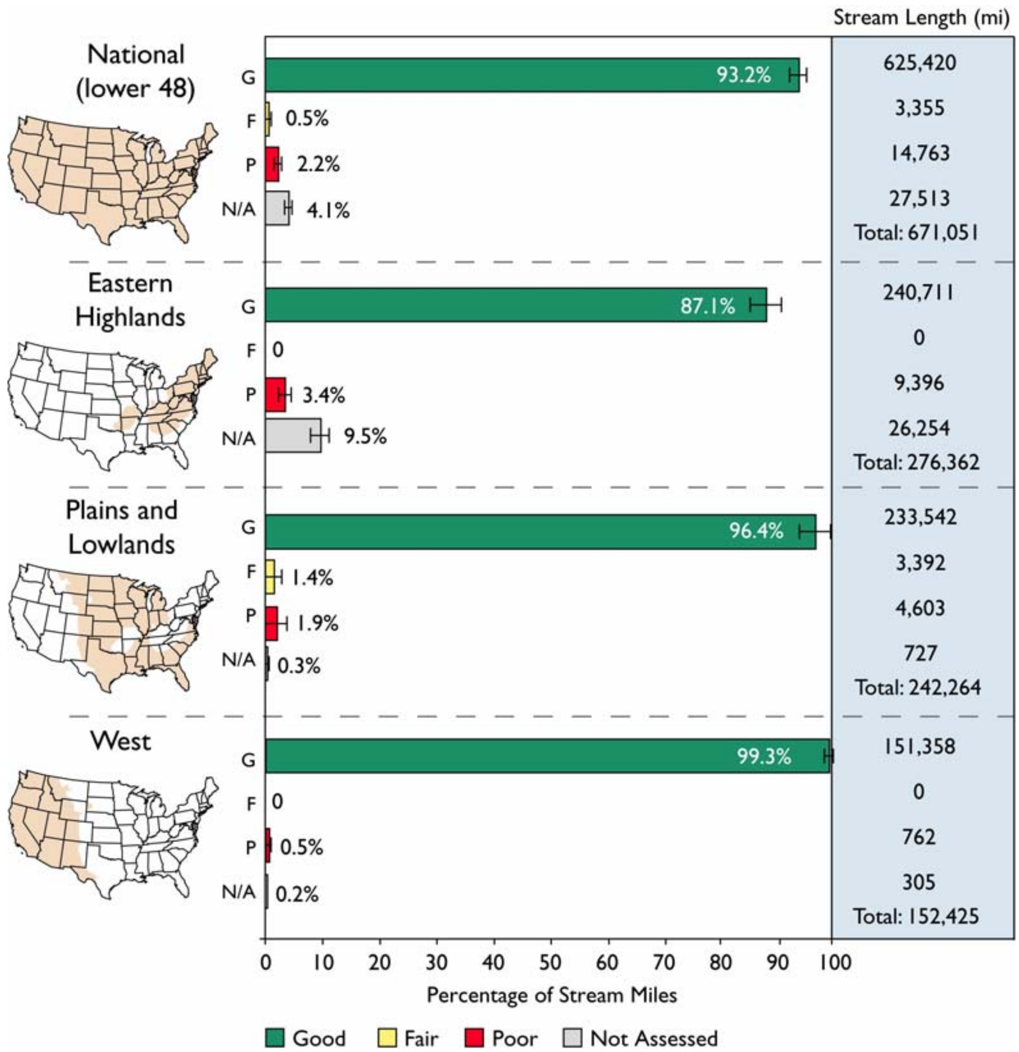


Figure 2-6. Acidification in U.S. streams.

Streams are acidic when acid-neutralizing capacity (ANC) values fall below zero. They are 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 levels of sulfate are associated with acid mine drainage. Low levels of sulfate indicate acid rain.

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 sediments on the stream bottom, which negatively impact macroinvertebrates and fish. Physical alterations to vegetation along the stream banks, alteration 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 altered or modified, the WSA focuses on four specific aspects of habitat: streambed sediments, in-stream habitat complexity, 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 the particle size of observed sediments to the size of sediments that each stream can move or scour during its flood stage (based on the size, slope, and other physical characteristics of the stream channel). The expected RBS ratio differs naturally among regions, depending upon landscape characteristics that include 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 in least-disturbed reference sites. Both high and low values are considered to be indicators of ecological stress. Excess fine sediments on the streambed 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. The WSA focuses on increase in streambed sediment, 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 fine sediment inputs, stressful ecological conditions can develop because fine sediments begin filling 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.

Findings for Streambed Sediments

Approximately 25% of the nation's stream miles have streambed sediment characteristics in poor condition compared to regional reference conditions (Figure 2-7). Streambed sediment characteristics are rated fair in 20% of stream miles and rated good in 50% of stream miles compared to reference. The two regions with the highest percentage of streams in poor condition are the Eastern Highlands (28%) and the Plains and Lowlands (26%), while the West region has the lowest percentage (17%) of streams in poor condition. Streams with significantly more stable streambeds than reference (e.g., evidence of hardening and scouring, streams that have been lined with concrete) were not included in this indicator. These stream conditions occurred so rarely in the survey that it was not necessary to separate them from the overall population.

Streambed Sediments

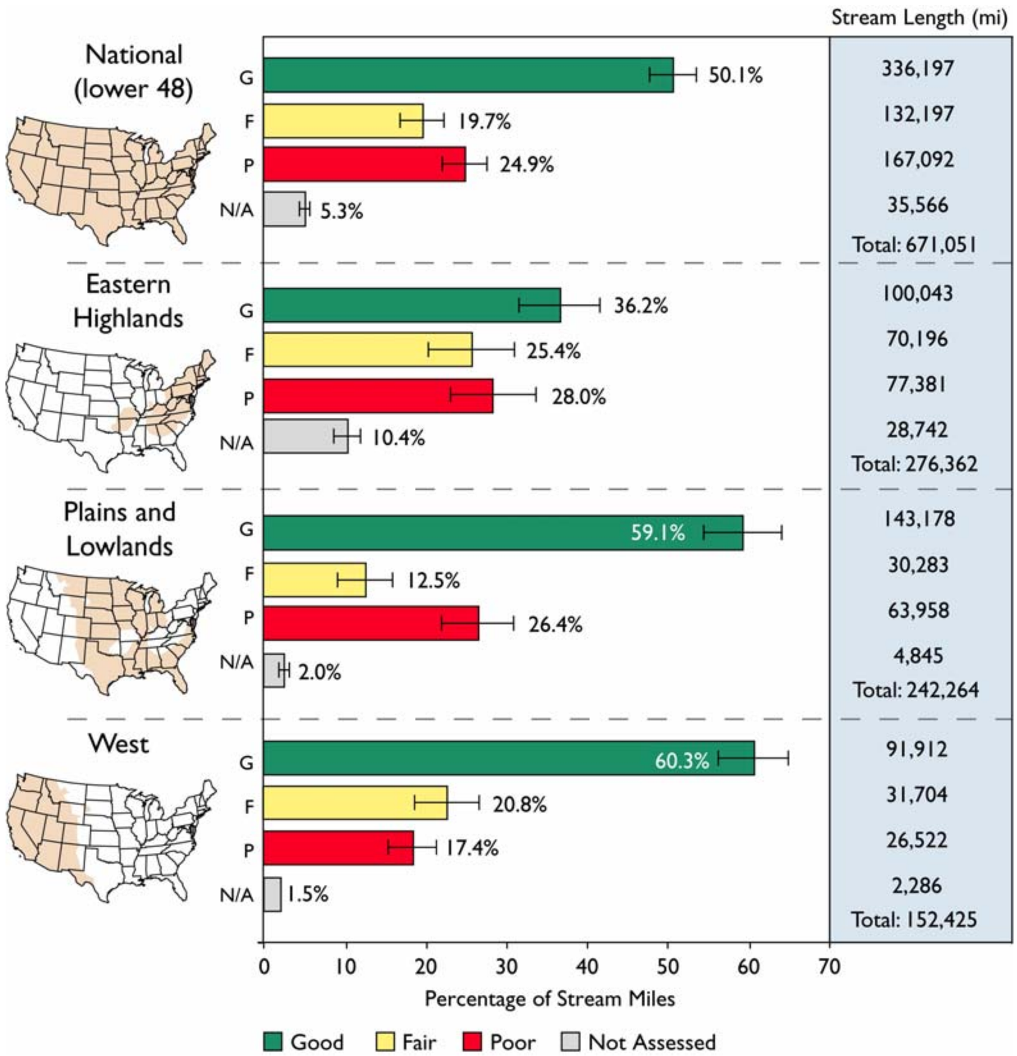


Figure 2-7. Streambed sediments in U.S. streams.

This indicator measures the percentage of stream beds impacted by increased sedimentation, which indicates alteration from reference conditions as defined by least-disturbed reference sites in each of the nine WSA ecoregions.

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 large wood within the stream banks, boulders, undercut banks, and tree roots. Human use of streams and riparian areas often results in the simplification of this habitat, with potential effects on biological 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

In-stream fish habitat is in poor condtion in 20% of stream miles across the United States. Twenty-five percent of stream miles are in fair condition, and 52% of stream miles are in good condition (Figure 2-8). The highest proportion in poor condition is in the Plains and Lowlands (37%); only 12% of stream miles in the West and 8% in the Eastern Highlands rated poor for in-stream fish habitat.

In-stream Fish Habitat

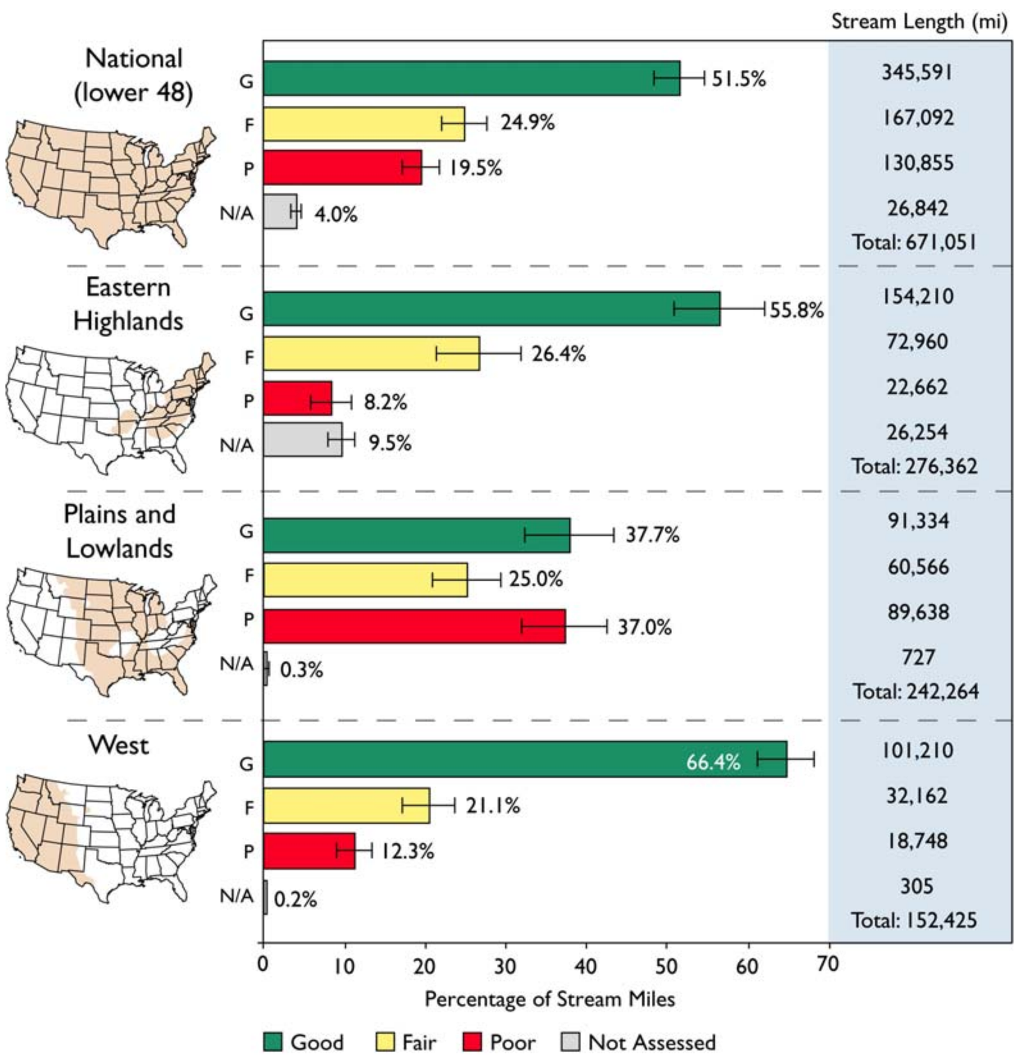


Figure 2-8. In-stream fish habitat in U.S. streams.

This indicator sums the amount of in-stream habitat that field crews found in the stream. Habitat consisted of undercut banks, boulders, large pieces of wood, and brush. Thresholds are based on conditions at regional reference sites.

Riparian Vegetative Cover

The presence of a complex, multi-layered vegetation corridor along streams and rivers is a measure of how well the stream network is buffered against sources of stress in the 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 that serve as food and habitat for stream organisms. The presence of large, mature canopy trees in the riparian corridor indicates its longevity, whereas 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 stream length nationally is in poor condition due to severely simplified riparian vegetation (Figure 2-9). About 28% of stream miles are in fair condition and almost half (48%) are in good condition relative to least-disturbed reference sites in the 9 WSA ecoregions. The West (12%) and Eastern Highlands (18%) have similar proportions of stream length with riparian vegetation in poor condition, though this equates to greater numbers of stream miles in the east where water is more abundant. In the Plains and Lowlands region, a larger proportion of stream length (26%) has riparian vegetation in poor condition.

Riparian Vegetative Cover

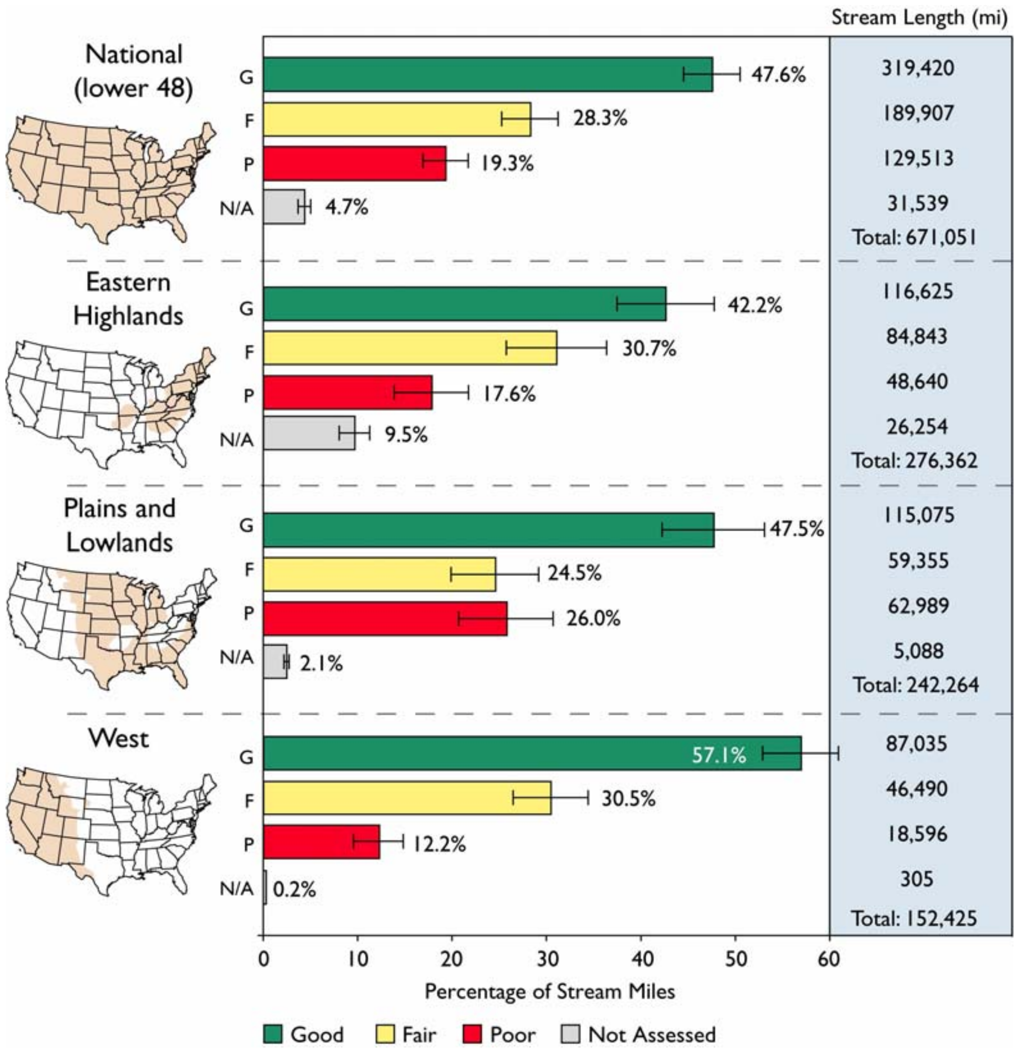


Figure 2-9. Riparian vegetative cover in U.S. streams.

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.

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 used a direct measure of riparian human disturbance that tallies 11 specific forms of human activities and disturbances along the stream reach and weights them according to how close they are to the stream channel. The index generally varies from 0 (no observed disturbance) to 6 (four types of disturbance observed in the stream, throughout the reach; or six types observed on the banks, throughout the reach).

Findings for Riparian Disturbance

Nationally, 26% of stream length has high levels of human influence along the riparian zone that fringes stream banks, and 24% has relatively low levels of disturbance (Figure 2-10). The highest proportion of stream length with high riparian disturbance is in the Eastern Highlands region (29%), followed by the Plains and Lowlands (26%) and the West (19%). One of the striking findings of the WSA is the widespread distribution of intermediate levels of riparian disturbance: 47% of United States streams have intermediate levels of riparian disturbance when compared to reference sites, and similar percentages are found in each of the three climatic and landform regions.

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

Riparian Disturbance

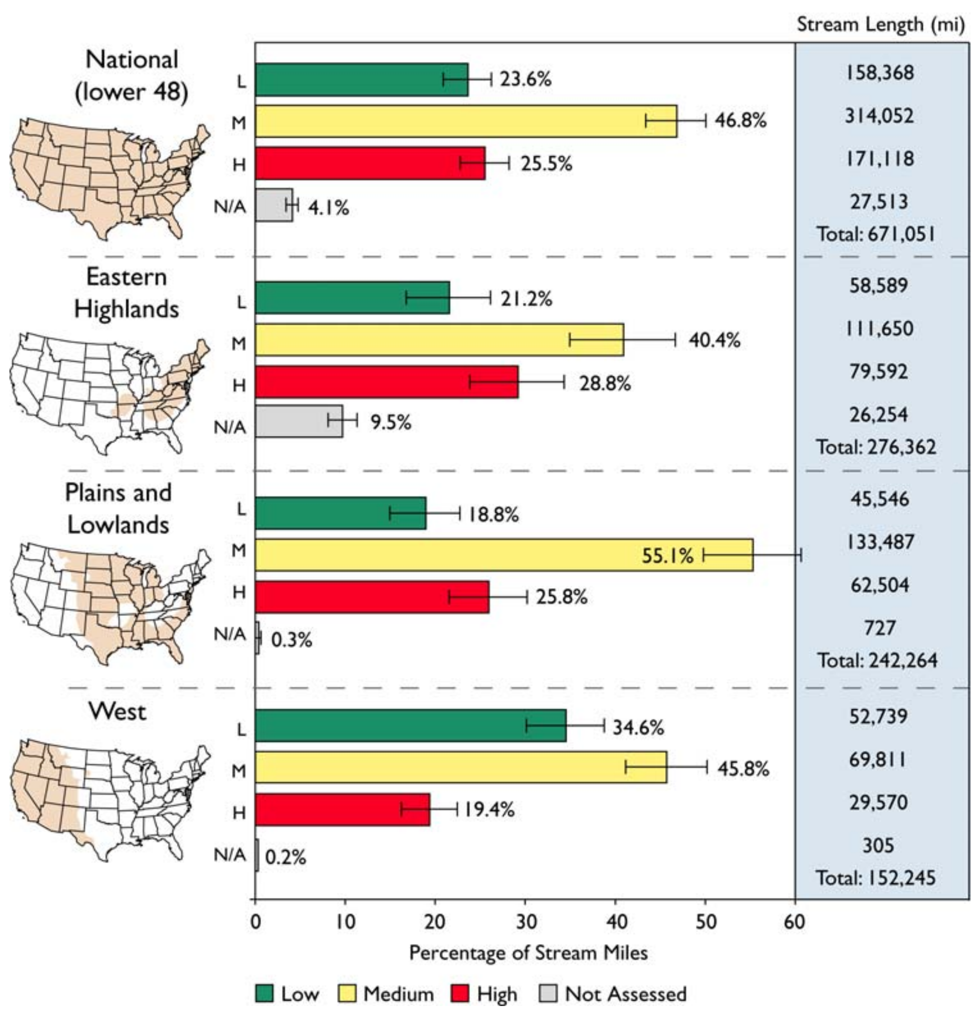


Figure 2-10. Riparian disturbance in U.S. streams.

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. Streams scored medium if human influence was noted at half of the plots and high if it was observed at all of the plots.

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 western mountains and deserts, 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 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 this initial assessment of streams, but may be included in future assessments.

Ranking of Stressors

An important 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 relative 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.

Relative Extent

Figure 2-11 shows the WSA stressors, each ranked according to the proportion of stream length that is in poor condition. Results are presented for the nation (top panel) and for each climatic and landform region, with the stressors ordered (in all panels) according to their relative extent nationwide.

Figure 2-11 reveals that excess total nitrogen is the most pervasive stressor for the nation overall, although it is not the most pervasive in each region. Nationally, approximately 32% of the stream length shows high levels of nitrogen compared to reference conditions. In the Plains and Lowlands, nitrogen is at high levels in 27% of stream length, whereas this proportion climbs to 42% in the Eastern Highlands. Even in the West, where levels of disturbance are generally lower than the other climatic regions, excess total nitrogen is found in 21% of the stream length. Phosphorus exhibits comparable patterns to nitrogen and is the second most pervasive stressor nationally.

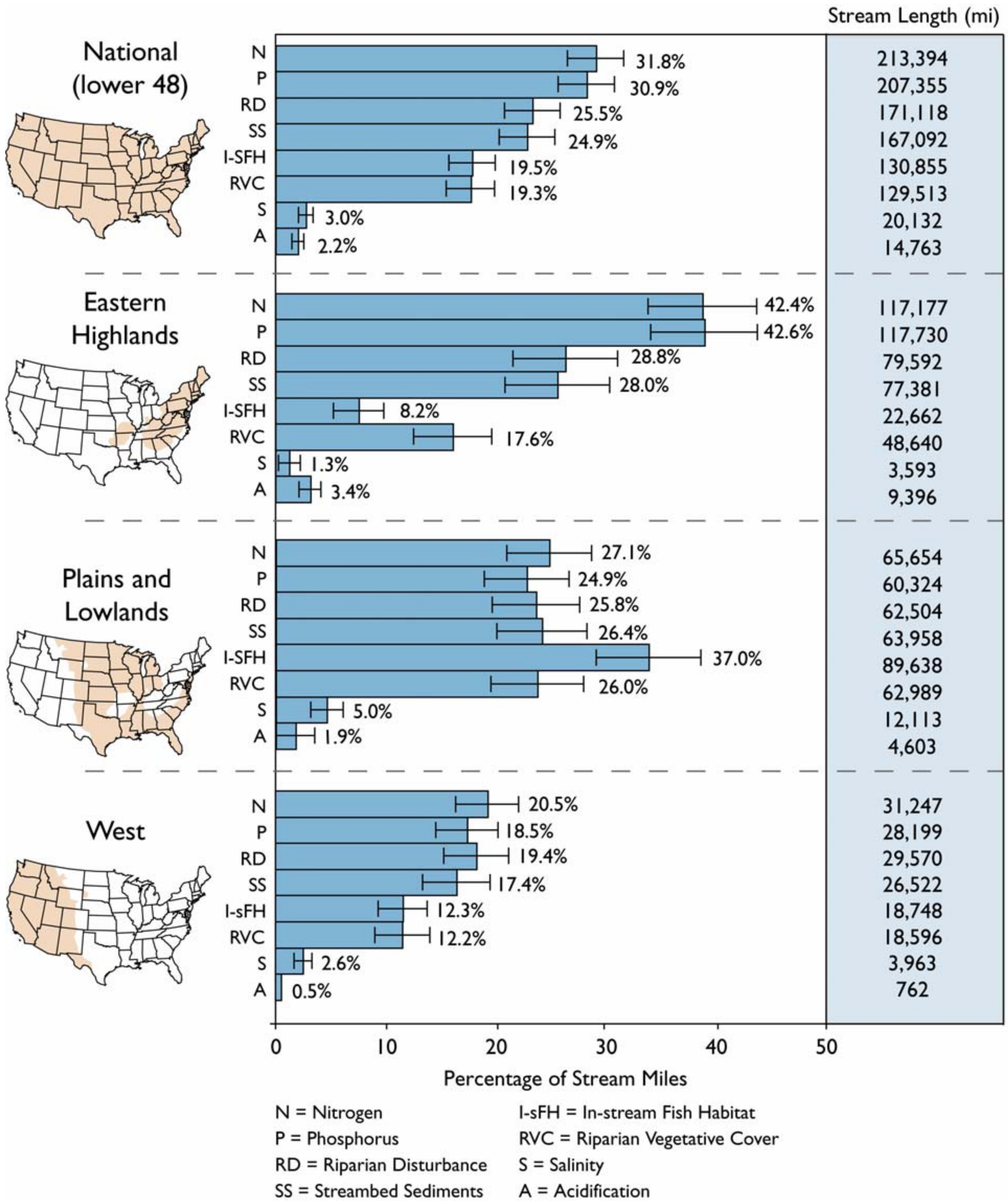


Figure 2-11. Relative extent of stressors (i.e., proportion of stream length ranked in poor category for each stressor).

The least common stressors nationally are salinity and acidification. Only 3% and 2%, respectively, of stream length across the lower 48 states have salinity and acidification levels in the most-disturbed category. 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, the stressor rated poor for the most stream miles is loss of in-stream fish habitat. In the Eastern Highlands, excess total nitrogen and excess total phosphorus levels are rated high in more than 42% of the stream length. In the West, all stressors are found in 21% or less of stream length, though nitrogen, phosphorus, and riparian disturbance are the most widespread stressors in this region as well.

Relative Risk of Stressors to Biological Condition

In order to address the question of severity of stressor effects, this report borrows the concept of relative risk from the medical field because of the familiarity of this language. We have all heard, for example, 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 four times higher for a person with total cholesterol level greater than 300 mg than for a person with total cholesterol of less than 150 mg.

The relative-risk values for stressors presented in Figure 2-12 can be interpreted in the same way as the cholesterol example. For each of the key stressors, this figure depicts how much more likely a stream is to have poor biological condition if a stressor is rated as poor or found in high concentrations than if the stressor is rated as good or found in 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 biological condition indicators.

A relative-risk value of one indicates that there is no association between the stressor and the biological indicator, whereas values greater than one suggest the stressor poses greater relative risk to biological condition. The WSA also calculates confidence intervals (Figure 2-12) for each relative risk ratio. When the confidence intervals for any given ratio do not include the value of one, the relative risk estimate is statistically significant.

The significant relative risks shown in Figure 2-12 give us an idea of the severity of each stressor's effect on the macroinvertebrate community in streams. Almost all of the stressors evaluated for WSA were associated with increased risk for macroinvertebrates. Evaluating relative risk provides insights as to which stressors we might focus on 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 taxa loss indicators. Findings show that relatively high levels of nutrients or excess streambed sediments increases the risk of finding poor macroinvertebrate condition by 2 to 4 times.

There are differences in relative risk from a geographic perspective. In general, the West region exhibits a higher relative risk for the majority of stressors than seen in 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 individual stressors that often occur together. For example, streams with high nitrogen concentrations often also exhibit high phosphorus levels, and streams with high riparian disturbance often have sediments far in excess of expectations. The analysis presented in Figure 2-12 treats the stressors as if they operate independently, even though we know they do not.

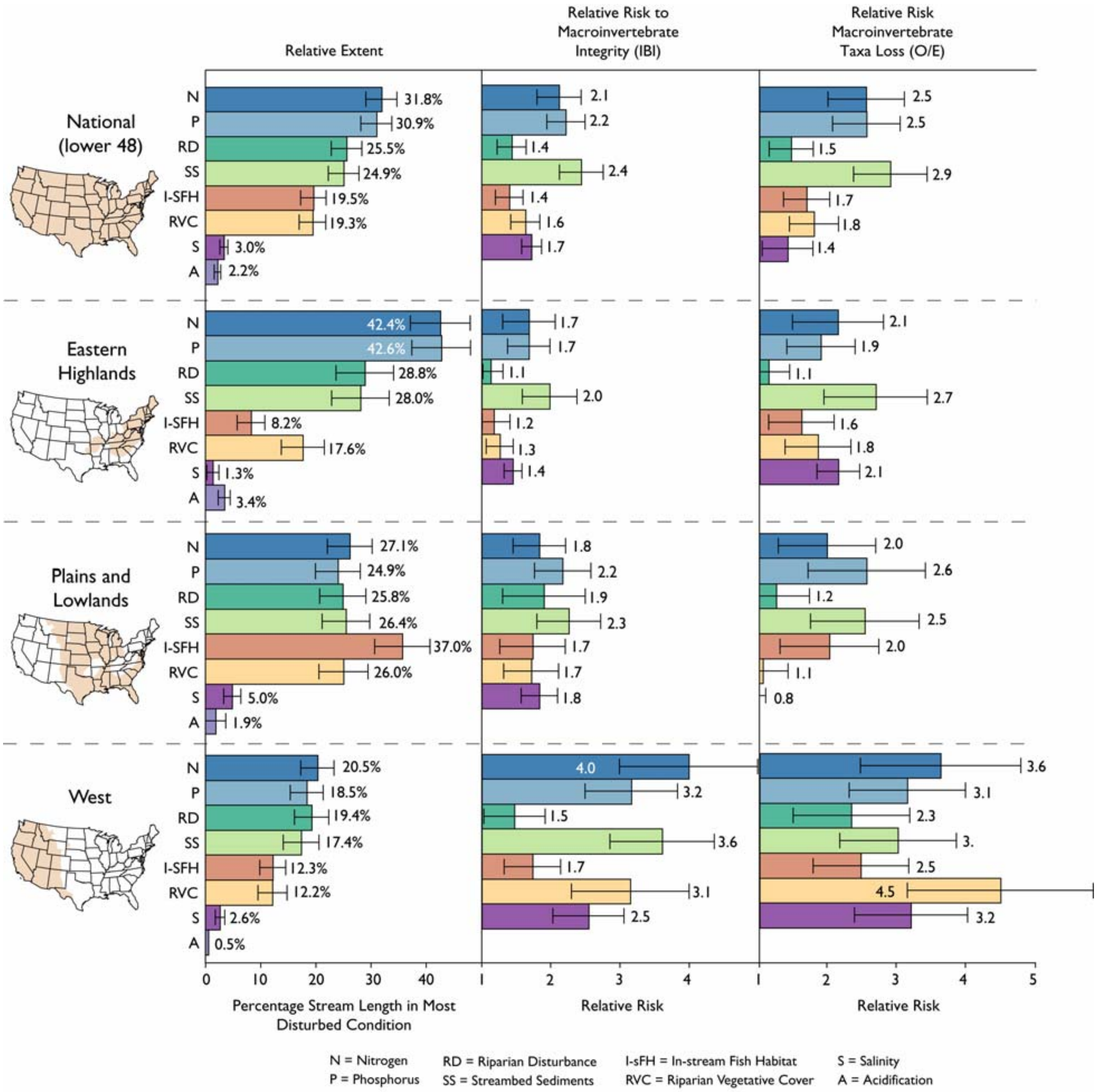


Figure 2-12. Relative extent of stressors and relative risk for Macroinvertebrate Index of Biotic Condition and macroinvertebrate taxa loss.

This calculation measures 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 calculation treats each stressor independently and does not account for the effects of combinations of stressors.

Combining Extent and Relative Risk

The most comprehensive assessment of the ranking of stressors comes from combining the relative extent (Figure 2-11) and relative risk (Figure 2-12) 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 extent in Figure 2-11) and whose effects are potentially severe (i.e., exhibit high relative risk ratios in Figure 2-12). The WSA facilitates this combined evaluation of stressor importance by including side-by-side comparisons of relative extent and relative risk in Figure 2-12.

A quick 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 stream length nationally. This suggests that management decisions aimed at reducing excess sedimentation and 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 region is strongly associated with poor biological integrity (relative risk = 2.5) and macroinvertebrate taxa loss (relative risk > 3.1 or = 3.2). However, its rarity (salinity affects only 3% of stream length in the West) 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 are consistently larger than for the nation overall or for the other two regions, yet the relative extent of these stressors is consistently lower in the West. This suggests that although the stressors are not widespread in the West, western streams are particularly sensitive to a variety of disturbances. Although this subject needs more investigation, this might be interpreted to mean that the apparently low relative risks in the Eastern Highlands and in the Plains and Lowlands reflect streams that may be less sensitive to stressors because of their longer history of disturbance.

Chapter 3 – Wadeable Streams Assessment Ecoregion Results

The WSA is designed to report on two geographic scales: a broader national scale and a finer ecoregional scale. Whereas Chapter 2 presented the national scale results, this chapter focuses on the results for nine ecological regions. Ecological regions are areas that contain similar environmental characteristics. Natural characteristics such as climate, vegetation, soil type and geology are used to create these regions. 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 nonpoint source pollution.

The nine WSA ecoregions are aggregations of the Level III ecoregions delineated for the conterminous United States. For each of the WSA ecoregions, this chapter provides background information on physical setting, biological setting and human influence. It also describes the WSA results for the wadeable stream length throughout the region.

Results for an ecoregion may not be extrapolated to an individual state or stream within the region 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 those characterizations are not described in this report.

The nine ecoregions encompass a variety of habitats and land-uses. 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. In a series of regional meetings, professional biologists examined the variability of reference sites and implications to the benchmarks used to characterize a region and to compare stream condition across regions. The benchmarks or thresholds were adjusted for those regions where there was a disturbance signal associated with the variability among reference sites. (Refer to Appendix A for more detail on the development of benchmarks or thresholds for each of the indicators.)

It should be noted that there are many specific and unique features within each ecoregion that are not fully captured in this report (see the References in Chapter 5 for more information). The nine ecoregions defined in this text are the following:

- Northern Appalachians (NAP)
- Southern Appalachians (SAP)
- Coastal Plains (CPL)
- Upper Midwest (UMW)
- Temperate Plains (TPL)
- Southern Plains (SPL)
- Northern Plains (NPL)

- Western Mountains (NMT)
- Xeric (XER)

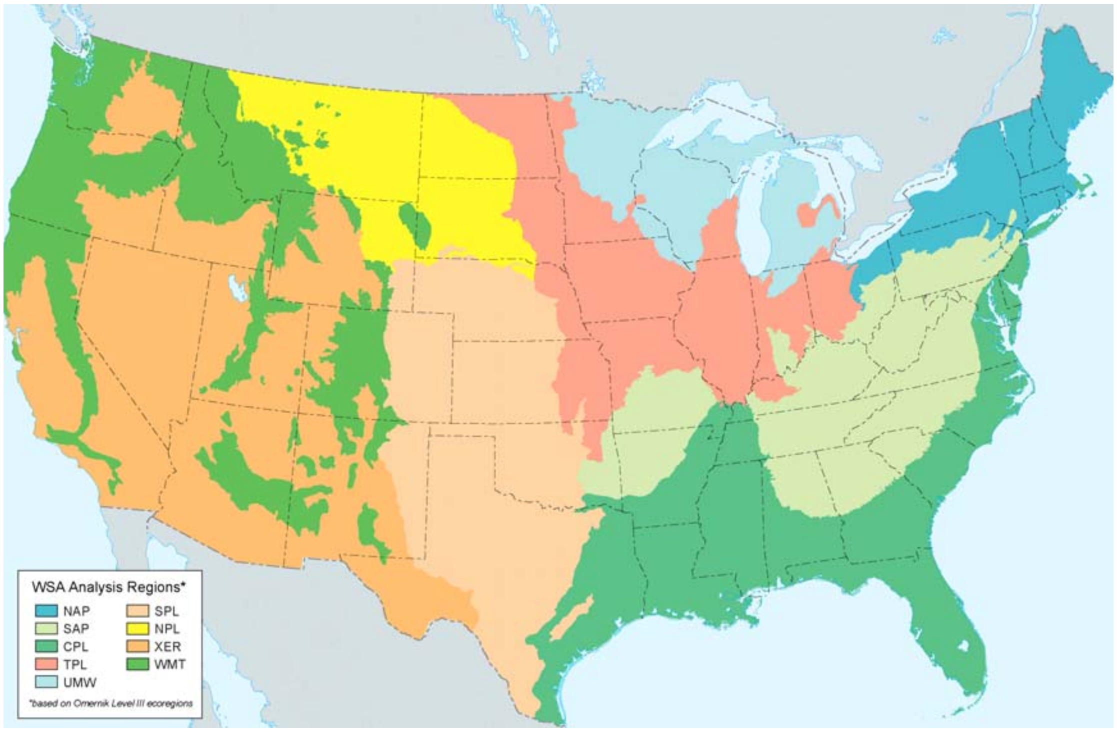


Figure 3-1. Ecological reporting regions for the Wadeable Streams Assessment.

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 northeast Ohio. It encompasses New York's Adirondack and Catskill mountains and Pennsylvania's mid-northern tier, including the Allegheny National Forest. Major river systems for this ecoregion are the St. Lawrence, Allegheny, Penobscot, the Connecticut, and the Hudson rivers. Major waterbodies include Lakes Ontario and Erie, New York's Finger Lakes, and Lake Champlain. There are 97,913 miles of wadeable streams in the Northern Appalachians that are represented by the WSA.

The topography 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. This ecoregion comprises some 139,424 mi^2 (4.6% of the United States), with about 4,722 mi^2 (3.4%) under federal ownership. Based on satellite images in the National Land Cover Dataset (1992), the distribution of land cover is 69% forested and 17% planted/cultivated, with the remaining 14% of land in other types of cover.

Biological Setting

Contemporary fish stocks are lower than at the time of European contact, but the coastal rivers of this 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, flushing sediment and decreasing diversity and availability of riparian habitat. Forests were cleared to introduce crops and pasture for grazing animals. Deforestation efforts caused the removal of sediments and nutrients and reduced riparian habitat. Roughly 96% of the original virgin forests of the eastern and central states was gone by the 1920s.

Smaller tributaries 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. This flushed sediment and wood downstream 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 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 into 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 deleted EPA Superfund National Priority List sites in this ecoregion.

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

This region also includes forestry, mining, fishing, and tourism. Agricultural activities include dairy cattle farming, potato production, poultry farming, timber harvesting, and wood processing of pulp, paper, and board.

The approximate population within the ecoregion is 40,550,000, which is about 14% of the total population of the United States.

Summary of WSA Findings

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

A total of 85 random sites were sampled during the summer of 2004 to characterize the condition of wadeable streams throughout the ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales. In a series of WSA regional workshops to evaluate the results, professional biologists expressed the view that many of the least-disturbed reference sites are nearly undisturbed streams with sparse human population in the immediate watershed. Therefore, the reference condition in the Northern Appalachians is of very high quality. An overview of the WSA survey results for the Northern Appalachian ecoregion is shown in Figure 3-2.

Biological Condition

- The findings of the Macroinvertebrate Index are that 45% of the stream length in this ecoregion is in poor condition, 15% is in intermediate or fair condition, and 13% is in good condition when compared to the least-disturbed reference condition. As noted above, 1st order streams, generally considered to be of high quality in this region, were not included in the assessment.
- O/E taxa loss results find that 50% of the stream length in the ecoregion has lost more than 10% of the macroinvertebrate taxa that are expected to occur, and 19% has lost 50% or more of its taxa. This indicator tells us that 23% of stream miles have 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 include total phosphorus, total nitrogen, streambed sediments, and riparian vegetative cover.

- About 45% of the total stream length in the ecoregion has high phosphorus levels compared to the relatively low levels found at reference sites, 16% has medium levels, and 12% has low levels.
- Similarly, about 45% of total stream length has high nitrogen levels, 10% has medium levels, and 18% has low levels compared to reference.
- Riparian disturbance evidence of human influence in the riparian zone is at high levels in 20% of the total stream miles, medium levels in 34%, and at low levels in 19% of stream miles.
- Salinity is found at high levels in 1%, at medium levels in 8%, and at low levels in 64% of stream miles.
- Analysis of physical stressors reveals that 29% of the total stream miles in the ecoregion are rated poor because of excess streambed sediments, 14% are in fair condition, and 28% in good condition compared to reference.
- For in-stream fish habitat, 16% of stream length is in poor condition, 13% is in fair condition, and 44% is in good condition compared to reference.

- Vegetative cover in the riparian zone along stream banks is in poor condition for 26% of the stream length, fair for 27%, and good for 20%.
- Acidification primarily associated with acid rain was detected in 3% of the total stream miles in the ecoregion.

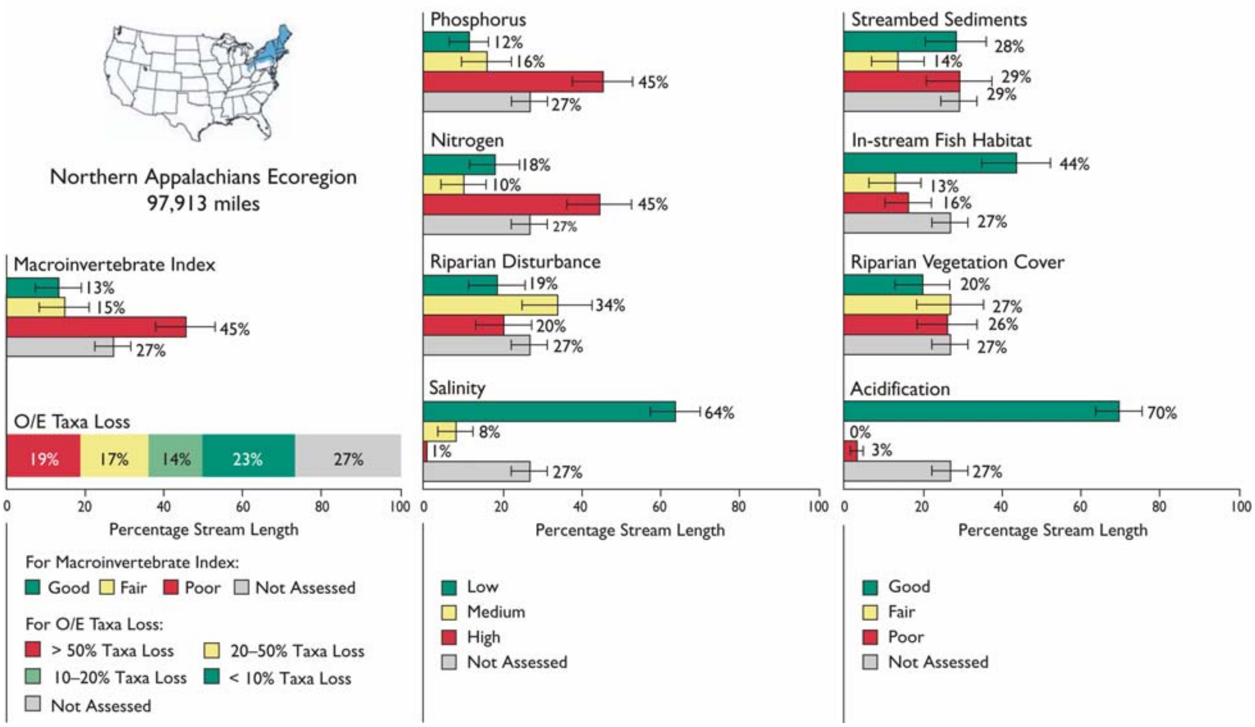


Figure 3-2. WSA survey results for the Northern Appalachians ecoregion.

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.

Southern Appalachians Ecoregion

Physical Setting

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

The region covers about 321,900 mi^2 (10.7% of the United States) with about 42,210 mi^2 (10.7%) under federal ownership. Many significant public lands, such as the Great Smoky Mountains National Park and surrounding national forests, the George Washington and Monongahela National Forests, and the Shenandoah National Park, reside within the region. 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-Mississippi systems such as the Greenbrier River in

West Virginia — originate in this region. There are 178,449 wadeable stream miles represented by the WSA for the Southern Appalachians Region.

The area's climate is considered temperate wet. Precipitation totals for the year average 40 to 80 inches. Mean annual temperature ranges from 55° to 65° F. Based on satellite images in the 1992 National Land Cover Dataset, the distribution of land cover is 68% forested and 25% planted/cultivated, with the remaining 7% of land in other types of cover.

Biological Setting

The region has some of the highest aquatic animal diversity of any area in North America, especially for species of amphibians, fishes, mollusks, aquatic insects, and crayfishes. Salamanders, plants, and fungi reach their highest North American diversity in the southern Appalachians; however, some 18% of animal and plant species in the region are threatened or endangered.

Some areas in the Southern Appalachians, such as the spruce-fir forests in the southern part of the region, are among the least impacted pre-settlement vegetative cover in the United States. 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 the stream length in the Southern Appalachians region. Placer mining began in the Appalachians in the 1820s. Placer mining disrupts stream beds and increases a stream's ability to transport finer sediments that disrupt habitat and water quality downstream. Between 1930 and 1971, some 800 mi^2 were surface mined in the Appalachian Highlands, leading to 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. Toxic contaminants from mining include 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. Petroleum and natural gas extraction are prevalent along the coal belt. Besides coal, other mining activities found in this ecoregion are bauxite, zinc, copper, and chromium mines. Utility industries include hydro-power in the Tennessee Valley and numerous coal-fired plants throughout the region. Significant agricultural activities are alfalfa production in Pennsylvania, with apple and cattle production throughout the region. Wood processing, pulp, paper, and board production are prevalent across the region.

Approximately 50,208,000 people live in the Southern Appalachians ecoregion, which is about 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 throughout the ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales. In a series of WSA regional workshops to evaluate the results, professional biologists expressed the view that the least-disturbed reference streams in the Southern Appalachians represent varying degrees of human influence. Although some streams are in remote areas, others are intricately linked with road systems in narrow floodplains. An overview of the WSA survey results for the Southern Appalachians ecoregion is shown in Figure 3-3.

Biological Condition

- The Macroinvertebrate Index tells us that 55% of the 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 reference.
- The O/E taxa loss results find that 65% of the stream resource in the region has lost more than 10% of the macroinvertebrate taxa that are expected to occur, and 16% has lost 50% or more of its taxa. This indicator tells us that 30% of stream miles have retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference conditions.

Indicators of Stress

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

- Phosphorus levels are high in 41% of stream miles, medium in 15%, and low in 44% when compared to least-disturbed reference condition.
- About 41% of wadeable stream miles in the region have high levels of nitrogen, 20% have medium levels, and 39% have low levels.
- Riparian disturbance is at high levels for 33% of stream miles, at medium levels for 44%. This evidence of human influence in the riparian zone is low for 23% of stream miles throughout the ecoregion.
- Only 2% of stream miles have high levels of salinity, 11% have medium levels, and the remaining 87% have low levels compared to reference condition.
- Streambed sediments are in poor condition in 27% of the stream length and in fair condition in 32% compared to least-disturbed reference condition. About 41% of stream miles are in good condition.
- In-stream fish habitat is in poor condition in 4% of stream miles, in intermediate or fair condition in 34% of stream miles, and in good condition in 62% of stream miles.
- Vegetative cover in the riparian zone along stream banks is in poor condition in 13% of the stream length, fair in 33%, and good in 54%.
- Acidification is rated in poor condition in 3% of the stream miles in the region due to acidic deposition and acid mine drainage.

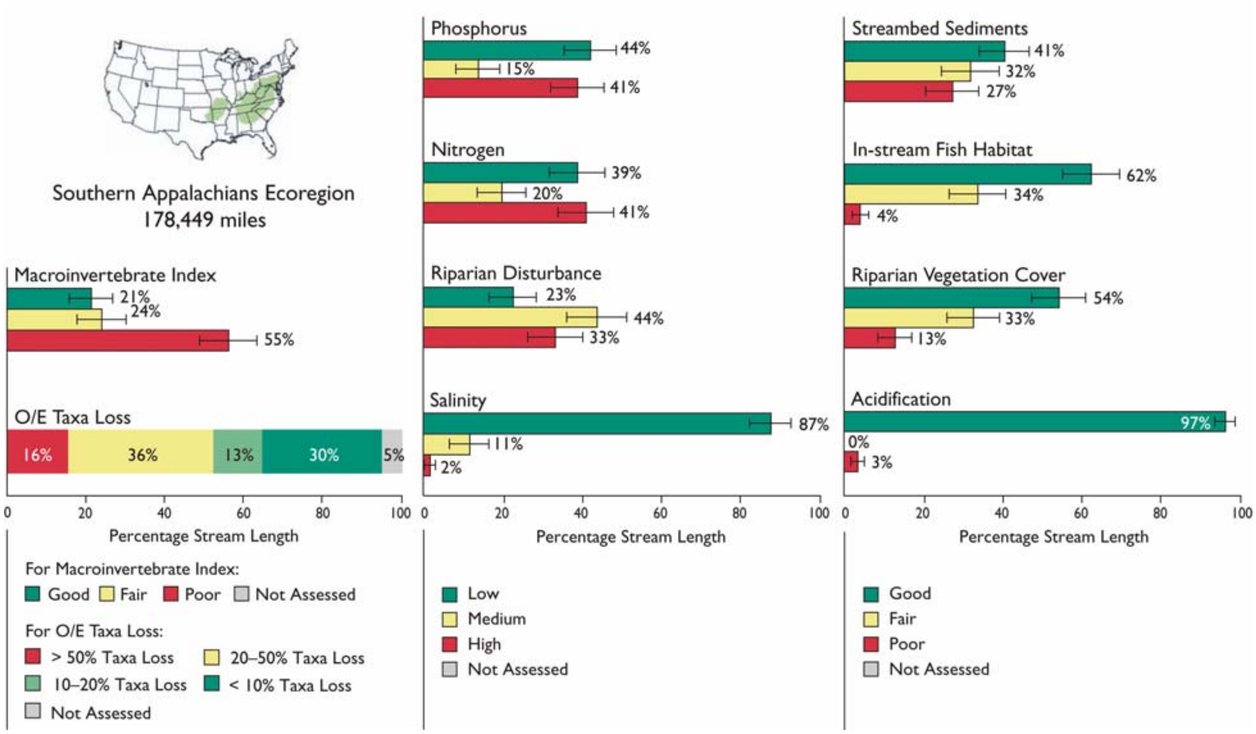


Figure 3-3. WSA survey results for the Southern Appalachians ecoregion.

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.

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, eastern Texas, and the Atlantic seaboard from Florida to New Jersey. Total area is about 395,000 mi^2 (13% of the United States) with 25,890 mi^2 (6.6%) under federal ownership. River systems lying within or intersecting the Coastal Plains are the Mississippi, Suwanee, 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, whereas 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. A total of 72,130 of wadeable stream miles in the Coastal Plains ecoregion are represented in the WSA.

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. 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 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 National Land Cover Dataset, the distribution of land cover is 39% forested, 30% planted/cultivated, and 16% wetlands, with the remaining 15% of land in other types of 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, and aquatic insect species include such unique species as paddlefish, catostomid suckers, American alligator, and giant aquatic salamanders. It is estimated, however, that some 18% of the aquatic species in this region are threatened or endangered. This ecoregion includes the Everglades, a unique ecosystem that contains temperate and tropical plant communities and a rich variety of species of birds and wildlife. However, because it is a unique aquatic ecosystem, the waters in the Everglades are not represented by the results of the WSA.

Human Influence

Historically, the Coastal Plains ecoregion had extensive bottomlands that flooded for several months, but 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, recreation, and the introduction of non-indigenous fishes and aquatic plants have also affected riparian habitats and aquatic fauna. There are currently 275 active, 13 proposed, and 77 deleted EPA Superfund National Priority List sites in this ecoregion.

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

The region also includes many large coastal cities, which contribute to a population of approximately 56,168,000, the largest population of all the WSA ecoregions and about 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 throughout the ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales. In a series of WSA regional workshops to evaluate the results, professional biologists expressed the view that the high prevalence of human population centers, agriculture, and industry makes it difficult to find truly undisturbed streams in the Coastal Plains ecoregion. Therefore, the least-disturbed reference sites in this ecoregion are influenced to some degree by human activities. An overview of the WSA survey results for the Coastal Plains ecoregion is shown in Figure 3-4.

Biological Condition

- The Macroinvertebrate Index reveals that 39% of the stream length in the Coastal Plains is in poor condition, 23% is in fair or intermediate condition, and 36% is in good condition compared to reference. No data are available for 2% of the resource.
- The O/E taxa loss indicator tells us that 65% of the stream length has lost 10% or more of the macroinvertebrate taxa that are expected to occur, and 15% has lost 50% of its taxa. This indicator tells us that 32% of stream miles have retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference conditions.

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.

- Phosphorus is found at high levels in 29% of stream miles, at medium levels in 13%, and in low levels in 58% of stream miles compared to least-disturbed reference condition.
- Nitrogen is high in 10% of stream miles, medium in 18%, and low in 72%
- Riparian disturbance is at high levels for 20% of stream miles and, at medium levels in 50%. This evidence of human influence in the riparian zone is at low levels for 30% of the stream length.
- In about 5% of stream miles, salinity levels are rated as high or medium; the remaining 95% of stream miles have low levels compared to reference.
- Streambed sediments are rated poor in 22% of the stream miles, in fair condition in 11%, in good condition in 64% compared to least-disturbed reference conditions, and there is no data for the remaining 3%.
- In-stream fish habitat is poor in 41% of stream length in the Coastal Plains, fair in 13%, and good in 46%, as compared to reference.
- Vegetative cover in the riparian zone along stream banks is in poor condition in 24% of the stream resource, in fair condition in another 24%, and in good condition in the remaining 52%.
- In this region, 6% of stream miles are rated poor because their acid neutralizing capacity is low enough to result in episodic acidification during rainfall. Another 5% have naturally lower pH.

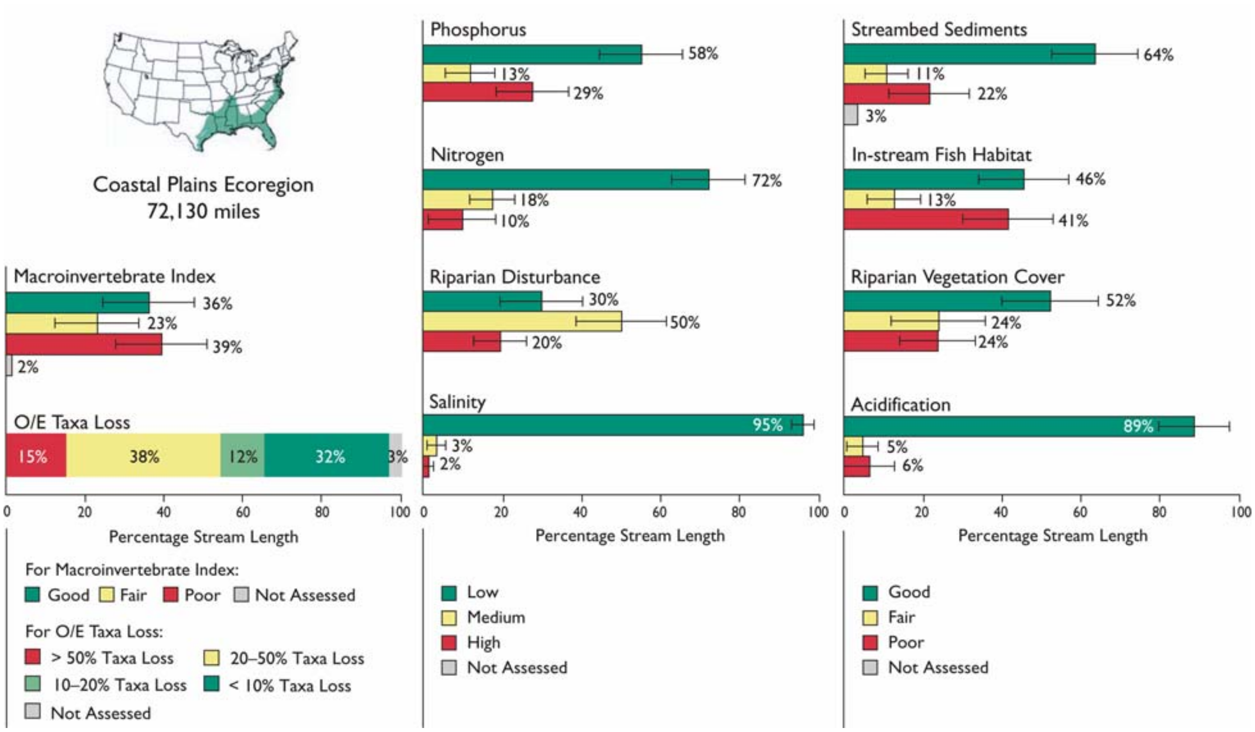


Figure 3-4. WSA survey results for the Coastal Plains ecoregion.

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.

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, extending about 160,374 mi^2 (5.4% of the United States). The river systems in this region empty into portions of the Great Lakes regional watershed and the Upper Mississippi watershed. Major river systems in this region include the upper Mississippi in Minnesota and Wisconsin; the Wisconsin, Chippewa, and St. Croix rivers in Wisconsin; and the Menominee and Escanaba rivers in Michigan. Streams typically drain relatively small catchments and empty directly into the Great Lakes or Upper Mississippi River. These streams tend to have steep gradients, but the topography and soils tend to slow runoff and sustain flow throughout the year.

A total of 36,547 wadeable stream miles in the Midwest ecoregion are represented in the WSA. Sandy soils dominate with relatively high water quality in streams supporting cold-water fish communities. Important water bodies include the Upper Mississippi River system and Lakes Superior, Michigan, Huron, and Erie. The climate is cool to temperate, with mean annual temperatures in the 40° to 54° range. Annual precipitation ranges from 28 to 47 inches.

The glaciated terrain of this ecoregion is typically 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 is covered by national and state forest. Federal lands account for 15.5% of the area at about 25,000 mi^2. Based on satellite images in the 1992 National Land Cover Dataset, the distribution of land cover is 40% forested, 34% planted/cultivated, and 17% wetlands, with the remaining 9% of land in other types of cover.

Biological Setting

Vegetative cover 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, like 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. 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 region. Pulp, paper, and board wood processing are prevalent throughout the northern parts of the region. The area includes the shipping ports at Duluth, MN, and Superior, WI, as well as cities like Marquette, Michigan and Hibbing, MN, which were built up along with the mining industry. The Upper Peninsula of Michigan lies entirely within this region, 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, or about 5% of the population of the United States.

Summary of WSA Findings

A total of 56 random sites were sampled during the summer of 2004 to characterize the condition of wadeable streams throughout the ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales. In a series of WSA regional workshops to evaluate the WSA results, professional biologists expressed the view that the least-disturbed streams that serve as a benchmark for reference condition in the Upper Midwest are mostly influenced by some form of human activity or land use. However, there are some streams in relatively undisturbed areas, particularly in the northern portion of the region. An overview of the WSA survey results for the Upper Midwest ecoregion is shown in Figure 3-5.

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 compared to least-disturbed reference condition.
- The O/E taxa loss indicator tells us that 54% of stream miles have lost 10% or more of macroinvertebrate taxa that are expected to occur, and 5% have lost 50% of taxa. This indicator reports that 45% of stream miles have 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.

- Phosphorus levels are high in 38% of stream miles, at medium levels in 18%, and at low levels in 42% compared to thresholds based on the least-disturbed reference condition for the region.
- Nitrogen is high in 21% of the stream length and medium in 30% of the stream length; in the remaining 48% of stream length, nitrogen is at low levels compared to least-disturbed reference condition.
- Riparian disturbance levels are high in 6% of stream miles and medium in 45%. This evidence of human influence in the riparian zone is low for 49%.
- Salinity is found at medium levels in 22% of stream miles.
- Fifty percent of stream miles are rated poor for excessive streambed sediments, 11% are rated fair, and 37% are rated good compared to least-disturbed reference condition. (There is no data on this stressor for 2% of the stream resource.)
- In-stream fish habitat is in poor condition in 17% of stream miles and fair condition in 69%, leaving 14% in good condition compared to reference.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 13% of stream length, fair condition for 38%, and in good condition for 44% of stream length.
- The effects of acidification are not noted in streams in this ecoregion.

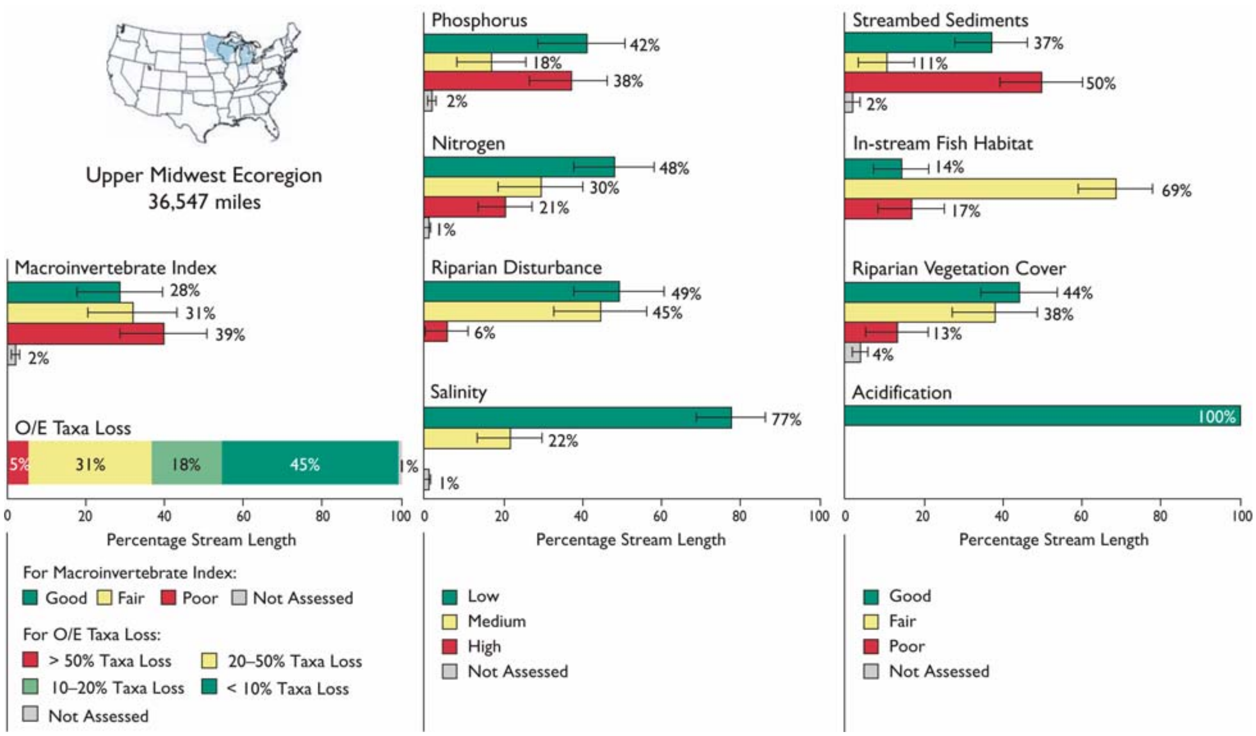


Figure 3-5. WSA survey results for the Upper Midwest ecoregion.

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.

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. This ecoregion covers some 342,200 mi^2 (11.4% of the United States), with approximately 7,900 mi^2 (2.3%) in federal ownership. The terrain consists of smooth plains, numerous small lakes, and wetlands. The climate is temperate, with fairly cold winters and hot, humid summers; mean temperatures range from 36° to 55° F. Precipitation ranges from 16 to 43 inches annually.

Many of the rivers in the region drain into the Upper Mississippi and Ohio regional watersheds. There are also a few systems that 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. A total of 100,879 wadeable stream miles in the Temperate Plains ecoregion are represented in the WSA. Based on satellite images in the 1992 National Land Cover Dataset, the distribution of land cover is 9% forested and 76% planted/cultivated, with the remaining 15% of land in other types of cover.

Biological Setting

Vegetation of the area consists primarily of oak, hickory, elm, ash, beech, and maple, with increasing amounts of prairie to the west. Rivers have rich fish fauna with many species, including minnows, darters, killifishes, catfishes, suckers, sunfishes, and black basses. Few species are endemic to the region, but have adapted to the warm, shallow creek environments.

Human Influence

Pre-settlement vegetation of the area was prairie grass and aspen parkland, but it is now 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 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 NAWQA 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 levels due to nutrients from agriculture and from fertilizer in urban areas applied to lawns and golf courses. 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 region. There are very active areas of manufacturing, steel production, and chemical production in the region'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. Many rivers, however, 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 this ecoregion.

The approximate population of this ecoregion is 38,399,000, about 13% of the population of the United States.

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 ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales.

In a series of WSA regional workshops to evaluate the WSA results, professional biologists expressed the view that it is hard to find high quality reference sites because even the least-disturbed streams in the Temperate Plains are influenced by a long history of land use. Extensive agriculture and development have influenced virtually all waterbodies in this region. An overview of the WSA survey results for the Temperate Plains ecoregion is shown in Figure 3-6.

Biological Condition

- The Macroinvertebrate Index reveals that 37% of stream length in the Temperate Plains ecoregion is in poor condition compared to reference, 37% is in fair condition, and 26% is in good condition compared to least-disturbed reference condition.
- The O/E taxa loss indicator tells us that 40% of stream miles have lost 10% or more of the macroinvertebrate taxa that are expected to occur, and 11% have lost 50% of taxa. This indicator reports that 58% of stream miles have retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference conditions.

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.

- About 12% of the stream miles have high levels of phosphorus and 13% have medium levels compared to this region's least-disturbed reference conditions. The remaining 74% have low levels.
- About 41% of the stream miles have high levels of nitrogen, 17% have medium levels, and 41% have low levels compared to thresholds based on the region's reference conditions.
- About 38% of the stream miles in this region have high levels of riparian disturbance, and the majority, 58%, have intermediate levels of disturbance in the riparian zone. Only 3% of the stream miles in the Temperate Plains have low levels of human influence in the riparian zone.
- Salinity is present at high levels in 2% of streams miles and at medium levels in 13%.
- Excess streambed sediments affect streams in this ecoregion to a lesser extent than the other physical stressors. Streambed sediments are rated in poor condition in 20% of stream miles, in fair condition in 12%, and in good condition in the remaining 67% of stream length.
- In-stream fish habitat is in poor condition in 39% of stream miles, in fair condition in 19%, and in good condition in 41%.
- About 26% of the stream length has poor riparian vegetative cover, 17% has fair or intermediate cover, and the remaining 53% has good cover.
- The effects of acidification are not noted in this region.

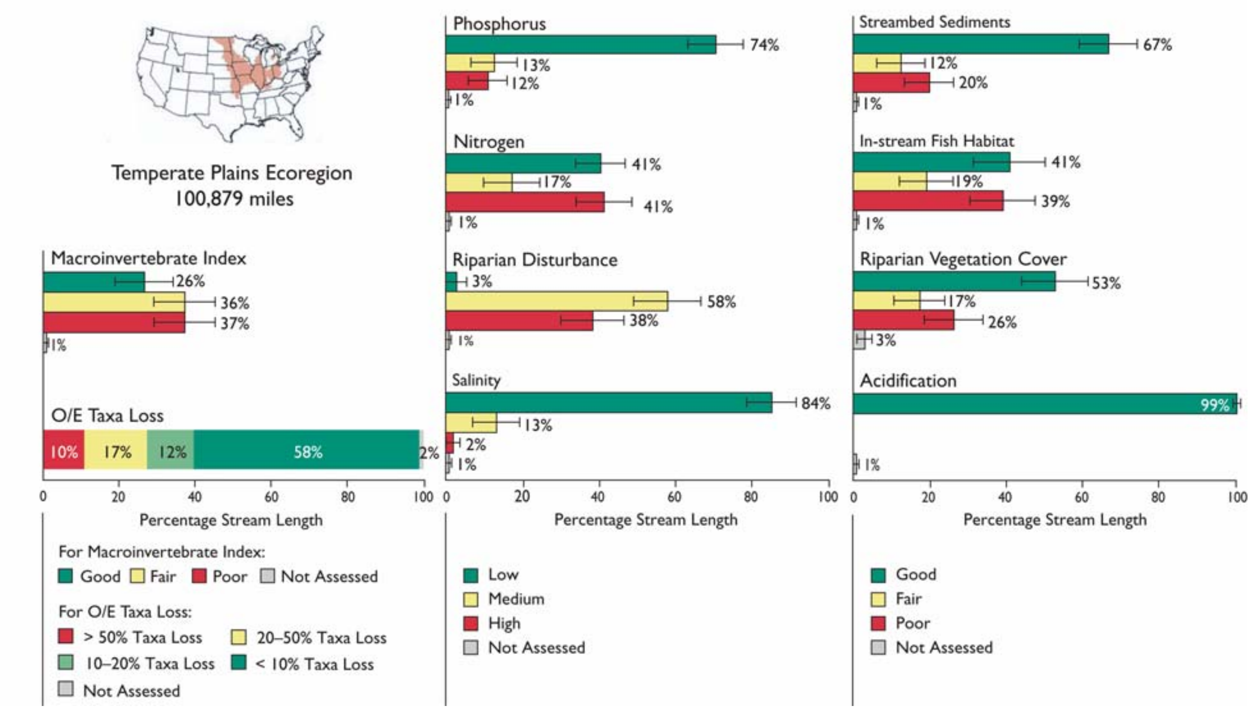


Figure 3-6. WSA survey results for the Temperate Plains ecoregion.

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.

Southern Plains Ecoregion

Physical Setting

The Southern Plains ecoregion covers approximately 405,000 (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 region, and most of the great Ogallala aquifer lies underneath this region. A total of 19,263 wadeable stream miles in the Southern Plains ecoregion are represented in the WSA.

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 National Land Cover Dataset, the distribution of land cover is 45% grassland, 32% planted/cultivated, and 14% shrubland, with the remaining 9% of land in other types of cover. Federal land ownership in the region 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 mean annual temperature in the 45° to 79° F range. Annual precipitation for the region is between 10 and 30 inches.

Biological Setting

Vegetative cover in the north is mainly short prairie grasses such as buffalo grass, while in the south, grasslands with mesquite, juniper, and oak are common. Coastal vegetation is typically more salt-tolerant in nature.

Human Influence

The Great Prairie grasslands, which once covered much of the Southern Plains region, 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 use. Agriculture is an important economic activity in this region and includes sorghum, wheat, corn, sunflower, bean, and cotton production. Livestock production and processing is prevalent, especially goats, sheep, and cattle. The region 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, which is 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 ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales.

At a series of regional workshops to evaluate results professional biologists expressed the view that no undisturbed streams remain in the Southern Plains region. The least-disturbed streams are those that retain natural configuration and have riparian buffer zones. An overview of the WSA survey results for the Southern Plains ecoregion is shown in Figure 3-7.

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 is no data for the remaining 4% of stream length.
- The O/E taxa loss indicator tells us that 50% of streams have lost 10% or more of the macroinvertebrate taxa expected to occur, and 15% have lost 50% of taxa. This indicator reports that 42% of the stream miles have 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.

- Phosphorus is found at high levels in 48% of the stream length, at medium levels in 7%, and at low levels in 45% of stream miles compared to thresholds based on least-disturbed reference condition.
- Nitrogen is high in 36% of stream miles, medium in 30%, and low in the remaining 34%.
- Riparian disturbance is rated as high in 19% of stream miles in this ecoregion. The majority of stream miles, 67%, are rated as medium, and only 14% are rated low for evidence of human influence in the riparian zone.
- Salinity is found at high levels in 22% of stream miles, at medium levels in 21%, and at low levels in 57%.
- About 30% of stream miles are rated in poor condition for excess streambed sediments. Streambed sediments are fair in 18% of stream miles and good in 52% of stream miles.
- About 42% of the stream resource has poor in-stream fish habitat and 23% has a fair rating; 35% is in good condition.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 36% of the stream length, in fair condition for 40%, and good condition for 24% of stream length.
- The effects of acidification are not noted in the Southern Plains region.

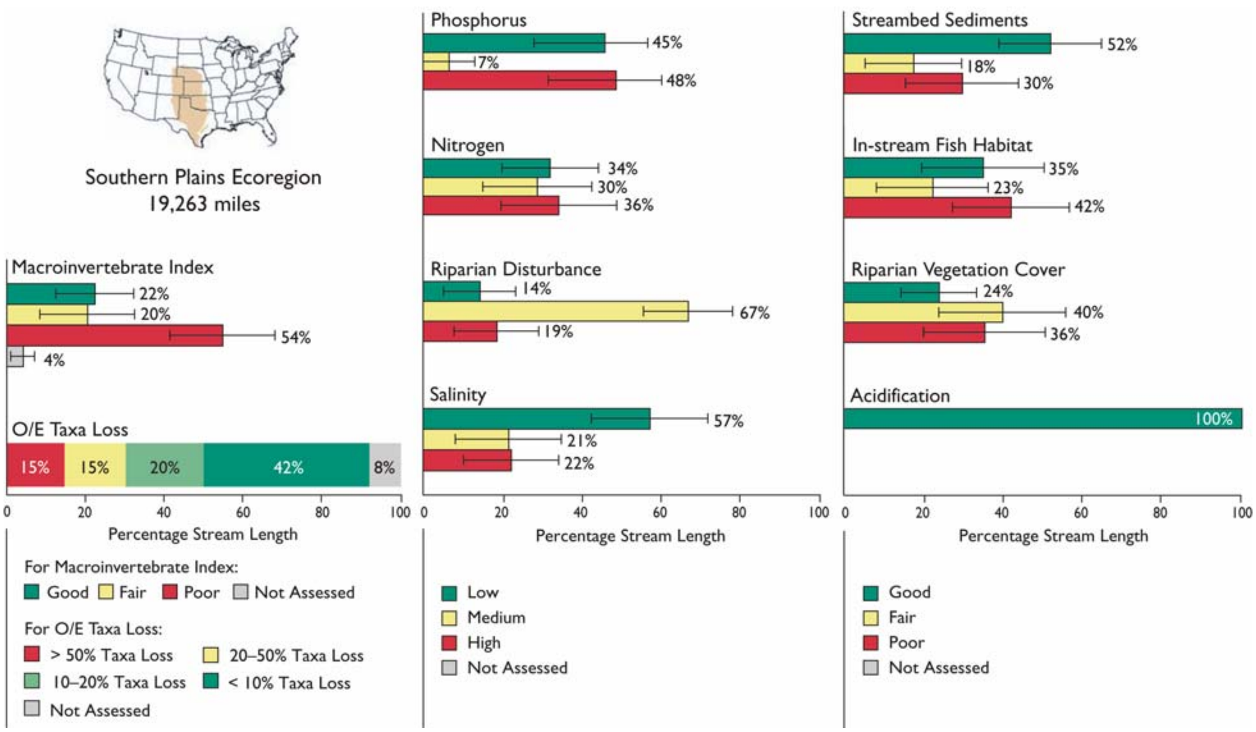


Figure 3-7. WSA survey results for the Southern Plains ecoregion.

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.

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 region, but about 90% of these grasslands have been replaced by other vegetation or land use. Terrain of the area 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. A total of 13,445 wadeable stream miles in the Northern Plains ecoregion are represented in the WSA.

Land use is arable with grazing or semi-arid grazing. Based on satellite images in the 1992 National Land Cover Dataset, the the distribution of land cover is 56% grassland and 30% planted/cultivated, with the remaining 14% of land in other types of 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 ecological region. 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.

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 region. Petroleum and gas production has grown considerably in the Cut Bank region in north central Montana. There are several large Indian reservations in this region, 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 ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales.

In a series of regional workshops, professional biologists expressed the view that while there are relatively few undisturbed streams in the Northern Plains ecoregion, the majority are in areas of low-level agriculture and pasture. An overview of the WSA survey results for the Northern Plains ecoregion is shown in Figure 3-8.

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 for the ecoregion. There is no data for the remaining 7% of stream length.
- The O/E taxa loss indicator tells us that 34% of stream miles have lost 10% or more of the macroinvertebrate taxa expected to occur, and 12% have lost 50% of their taxa. This indicator reports that 60% of stream miles have 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.

- Phosphorus is high in 33% of stream miles and medium in 13%. The remaining 54% of streams have low phosphorus levels compared to thresholds based on least-disturbed reference condition for the ecoregion.
- Nitrogen is high in 18% of stream miles and medium in 21%. It is found in low levels in 60% of stream miles.
- Riparian disturbance is high in 31% of stream length and medium in 66%. This evidence of human influence in the riparian zone is low for 3% of stream miles.
- Salinity is a significant stressor in the Northern Plains. Salinity is high in 38% of stream miles, medium in 22%, and low in 40% compared to reference-based thresholds.
- In this ecoregion, 33% of stream miles are rated poor for excess streambed sediments, 14% are rated fair, and 50% are rated good. There is no sediments data for 2% of stream length in this region.
- In-stream fish habitat is poor in 45% of streams, fair in 21%, and good in 34%.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 50% of stream miles, in fair condition for 22% of stream miles, and in good condition for 28% of stream miles.
- As with several other ecoregions, the effects of acidification are not noted in the Northern Plains.

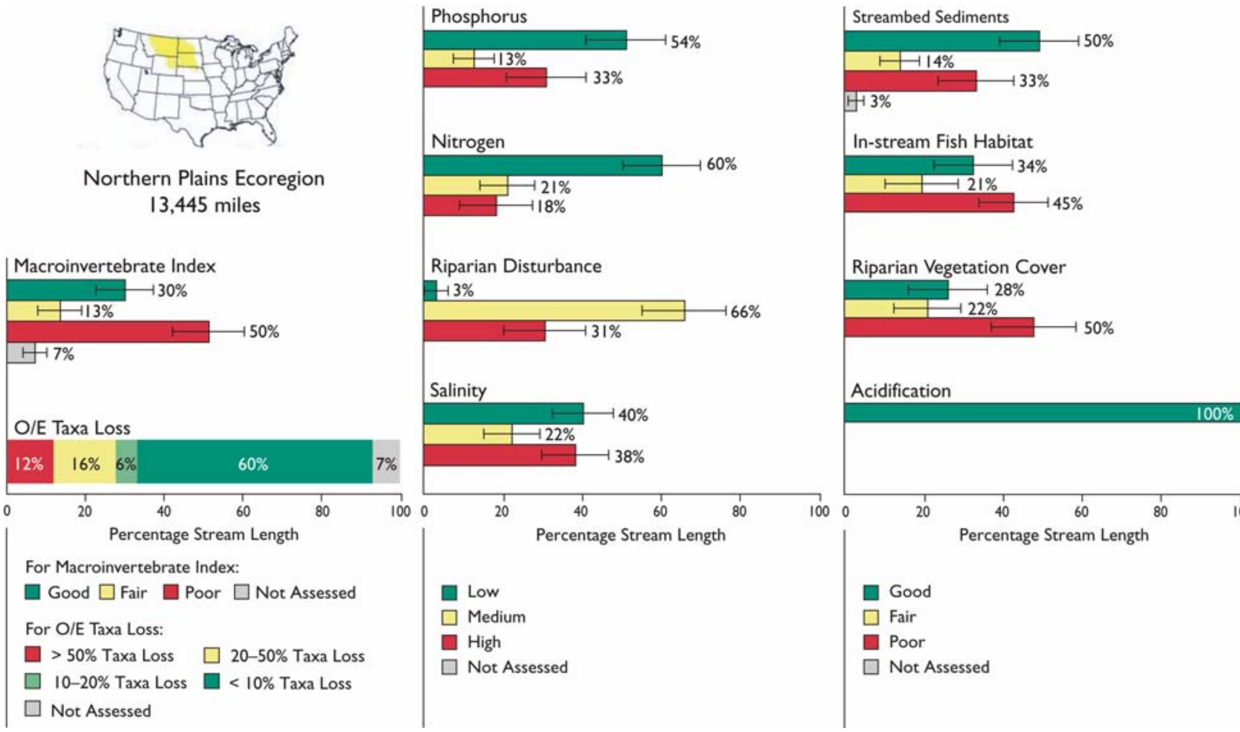


Figure 3-8. WSA survey results for the Northern Plains ecoregion.

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.

Western Mountains Ecoregion

Physical Setting

The Western Mountain ecoregion includes the Cascade, Sierra Nevada, Pacific Coast ranges in the coastal states, the Gila Mountains in the south western states, and the Bitteroot and Rocky Mountains in the northern and central mountain states. This region 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 cut through by numerous fjords and glacial valleys, 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 National Land Cover Dataset, the distribution of land cover is 59% forested, 19% shrubland, and 13% grassland, with the remaining 9% of land in other types of cover.

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

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 region. Mean annual temperatures are in the 32° to 55° F range, and annual precipitation ranges from 16 to 240 inches.

Biological Setting

Rivers in this ecoregion drain dense forested catchments and contain a lot of wood that provides 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, and 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 Mountain 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 that occur to the present day.

Placer mining, which disrupts stream sediment habitats, was once widespread in the Western Mountains. 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, 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 region. There are currently 74 active, 7 proposed, and 22 deleted EPA Superfund National Priority List sites in this ecoregion.

The approximate population in the Western Mountain ecoregion is 9,742,192, or about 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 ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales.

In a series of regional workshops, professional biologists expressed the view that many least-disturbed streams in the Western Mountain ecoregion are of relatively high quality; however, a certain percentage of these streams have mining and logging impacts, leading to reference conditions of varying degrees of quality. An overview of the WSA survey results for the Western Mountains ecoregion is shown in Figure 3-9.

Ecological 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 is no data for about 1% of stream length.
- The O/E taxa loss indicator tells us that 33% of streams have lost 10% or more of the macroinvertebrate taxa expected to occur, and 5% have lost 50% of taxa. This indicator tells us 63% have 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.

- Phosphorus is rated as high in 16% of stream length, medium in 25%, and low in 59%.
- Nitrogen is found at high levels in 17% of streams, at medium levels in 28%, and at low levels in 54% relative to the least-disturbed reference condition.
- Riparian disturbance is at high levels in 14% of stream miles and at medium levels in 47%. This evidence of human influence in the riparian zone is low for 39% of stream miles.
- Salinity is found at low levels in about 3% of streams in the region.
- In this ecoregion, 14% of stream miles are rated poor for excess streambed sediments, 22% of streams are rated in fair condition; the remaining 63% are in good condition.
- In-stream fish habitat is in poor condition in 9% of stream miles. Another 20% are rated as fair, and 70% are rated good for this indicator.
- Vegetative cover in the riparian zone along stream banks is in poor condition for 9% of stream miles, fair for 32% of stream miles, and good for 59% of steam miles.
- The effects of acidification are not noted in this region.

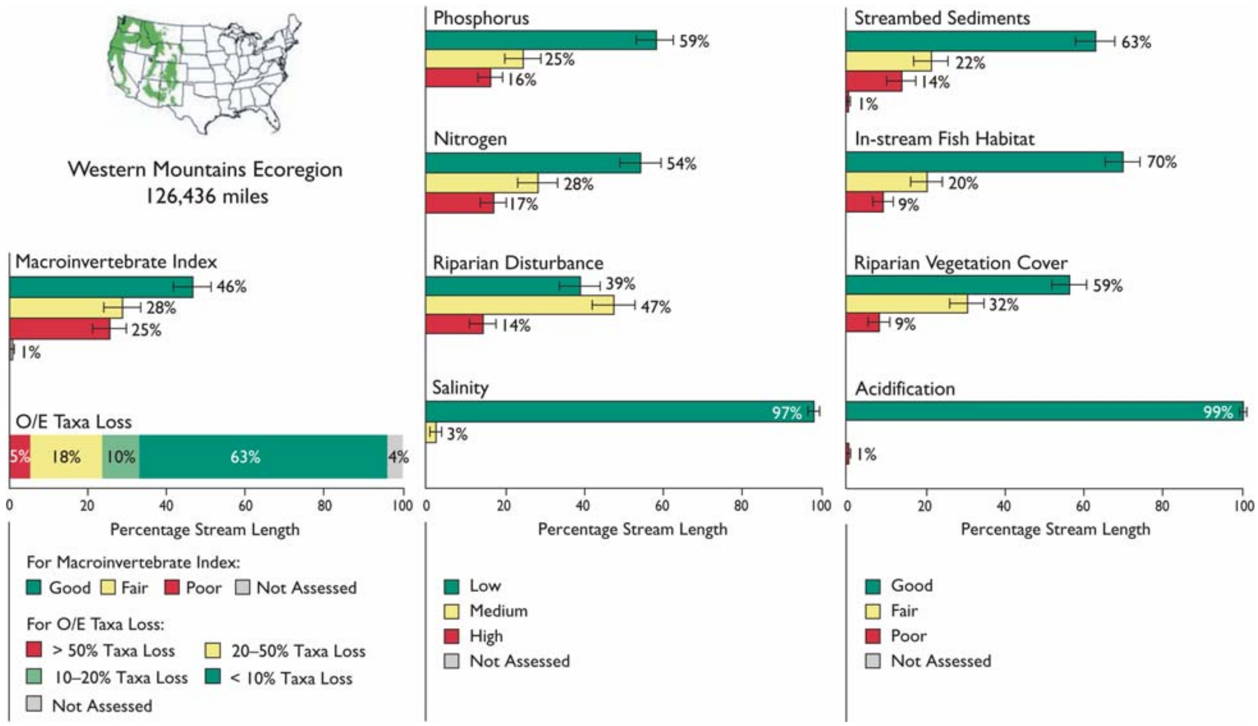


Figure 3-9. WSA survey results for the Western Mountains ecoregion.

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.

Xeric Ecoregion

Physical Setting

The Xeric ecoregion covers the largest area of all WSA aggregate ecoregions and 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 National Land Cover Dataset, the distribution of land cover is 61% shrubland and 15% grassland, with the remaining 24% of land in other types of 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 region 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 region'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 and are supplied by snowmelt 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). A total of 25,989 miles of wadeable streams in the Xeric ecoregion are represented in the WSA.

The Xeric region'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 fishes are endemic and 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 fishes are threatened or endangered as a result of flow regulations from dams, water withdrawals, and introduced non-native species. Endangered 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 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 region. Riparian habitats in this region 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, and 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 ecoregion. The regional results may not be extrapolated to an individual state or stream within the region because the study design was not intended to characterize stream conditions at these finer scales.

In a series of regional workshops to evaluate the results, professional biologists expressed the view that many of the perennial, least-disturbed streams in this region have been influenced by past and current human activities. An overview of the WSA survey results for the Xeric ecoregion is shown in Figure 3-10.

Biological Condition

- The Macroinvertebrate Index reveals that 39% of stream length in the Xeric ecoregion is in poor condition compared to least-disturbed reference, 15% is in fair condition, and 42% is in good condition. There is no data for about 4% of stream length.
- The O/E taxa loss indicator tells us that 61% of streams have lost 10% or more of the macroinvertebrate taxa expected to occur, and 15% have lost 50% of taxa. This indicator tells us 34% have retained 90% of the groups or classes of organisms expected to occur based on least-disturbed reference condition.

Indicators of Stress

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

- Phosphorus is found at high levels in 29% of stream miles, at medium levels in 10% and at low levels in 60% of stream miles. About 1% of streams in this ecoregion have no data for phosphorus.
- Nitrogen is the leading chemical stressor in the Xeric region. It is found at high levels in 36% of stream miles, at medium levels in 26%, and at low levels in 37% of stream miles.
- Riparian disturbance is the leading physical stressor for the Xeric region. It is found at high levels in 44% of stream miles in this ecoregion and medium levels in 40%. The remaining 14% of stream miles have low levels evidence of human influence in the riparian zone.
- Salinity is rated high in 13% of stream miles and medium in 29%, with the remaining 56% rated as low. About 1% of stream miles have no data for salinity.
- In this ecoregion, 32% of stream miles are rated poor for excess streambed sediments, 17% are rated fair, and 48% of stream miles are rated in good condition. For 3% of streams, there is no data for sediments.
- In-stream fish habitat is poor in 27% of streams, fair in 25% of streams, and good in 47%. The remaining 1% of streams have no data on this stressor.

- Vegetative cover in the riparian zone along stream banks is in poor condition for 28% of streams, in fair condition for 21% of streams, and in good condition for 49% of streams of the Xeric region.
- As with a number of other ecoregions, the effects of acidification are not noted in the Xeric ecoregion.

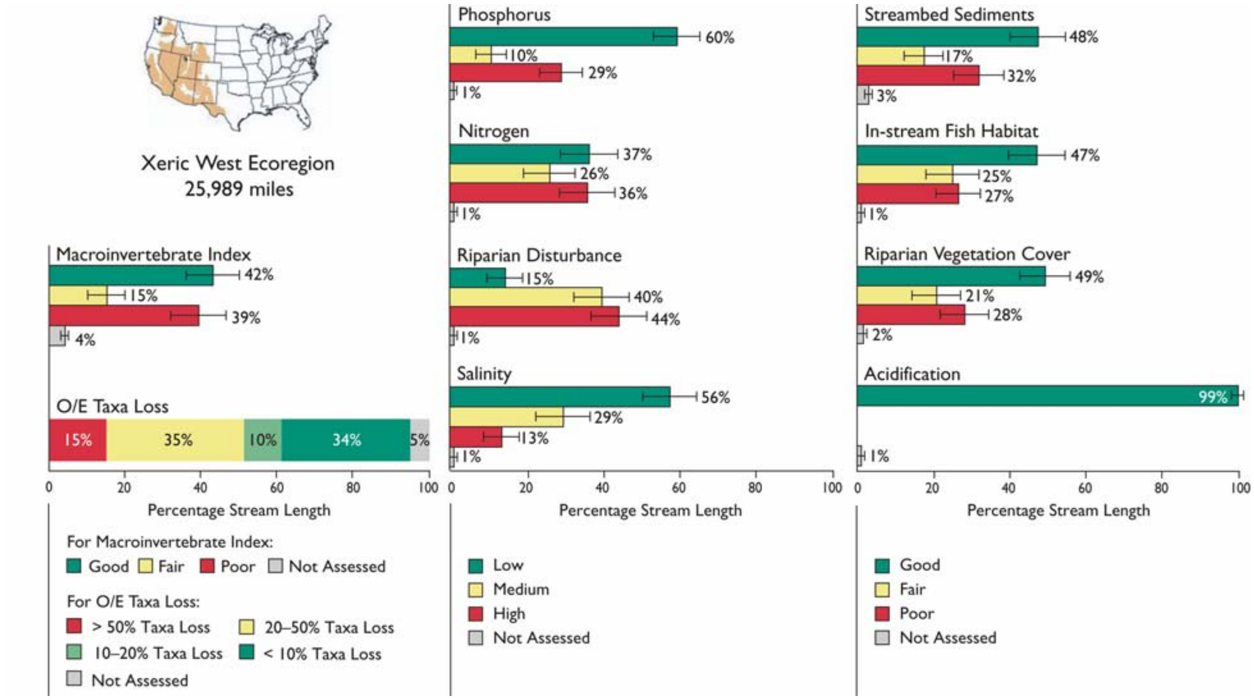


Figure 3-10. WSA survey results for the Xeric ecoregion.

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.

Chapter 4 – Conclusion and Next Steps

The United States covers an enormous and diverse landscape. Not surprisingly, the ecological condition of U.S. streams varies widely geographically. Forty-two percent of the nation's stream length is in poor biological condition. The most widespread or common stressors are nutrients (e.g., phosphorus and nitrogen), riparian disturbance, and excess streambed sediments. Nationally, the high levels of nutrients and excess sedimentation more than double the risk of poor biological condition.

The Eastern Highlands region has the highest amount of stream miles rated in poor condition. In this region, the Macroinvertebrate Index of Biotic Condition shows that 52% of the Eastern Highlands stream resource is in poor condition when compared to least-disturbed reference sites in the region. This is somewhat confounded by the deletion from the survey of small headwater streams in New England, which are both numerous and tend to be in better condition than larger streams.

Geographically, the nation's total stream length is not evenly distributed. The densest stream coverage is in the Eastern Highlands region, which has approximately 276,362 miles of perennial streams. The Plains and Lowlands region, which covers a large portion of the United States, has 242,256 miles of perennial streams, and 40% of these are rated poor. Although streams in the West appear to be in better condition when compared to least-disturbed reference condition (27% in poor condition), this region only has 152,425 miles of perennial streams, about 23% of the total stream length; therefore, it is important to evaluate the results in terms of both percentages and absolute stream miles. For example, the percentage of streams in good condition varies dramatically between the West and Plains and Lowlands regions – 45% in the West and 29% in Plains and Lowlands. If these percentages are converted to absolute length of stream, the West region has 68,851 miles in good condition, whereas the Plains and Lowlands region has 70,530 miles in good condition.

In addition to characterizing the condition of the nation's streams resource, the WSA provides a valuable opportunity to explore technical and programmatic elements of stream assessment. Important technical evaluations to follow this report will include the comparability studies being performed by a number of WSA partners. These studies will report on collected samples using a variety of sampling methods to explore the potential to integrate and share data from multiple sources. Another priority being addressed by states and EPA is an improved understanding of reference condition and how it is used to define expectations for the nation's waterbodies. EPA's Office of Science and Technology will also be evaluating WSA data in developing and evaluating water quality criteria for nutrients and excess streambed sediments. The WSA has, in short, provided a rich data set and sparked interest in many additional areas of investigation.

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. The Highlight on acidification trends and the Clean Air Act (below) 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 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 assessed recent changes in surface water chemistry in the northern and eastern United States to evaluate the effectiveness of the CAAA (Stoddard et al., 2003). At the core of the monitoring, known as the TIME project, was the concept of a probability survey, where a set of sampling sites were 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 Northern Appalachians.

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

Region	Population Size							
New England	6,834 lakes	386 lakes	5.6%	1991-1994	+0.3	374 lakes	5.5%	-2%
Adirondacks	1830 lakes	238 lakes	13.0%	1991-1994	+0.8	149 lakes	8.1%	-38%
No. Appalachians	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 acid-neutralizing capacity (using the analytical technique of Gran titration, with the result know 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.

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Appendix A

2006 Wadeable Streams Assessment: Data Analysis Approach

Overview

This appendix provides additional information to supplement the results and discussion presented in the 2006 Wadeable Streams Assessment (WSA). It is intended to provide a more technical reference than the report itself on the conceptual basis and the methods and procedures used for the WSA. Although it is intended to provide a comprehensive summary of these procedures, it is not intended to present additional data analysis results or an in-depth report of the design, sampling, or analysis protocol. For additional details, citations are provided.

Objectives of the WSA Assessment

The objective of the WSA assessment is to characterize the ecological condition of wadeable streams and rivers throughout the conterminous United States. The WSA is an ecological assessment of streams based on chemical, physical, and biological data. It employs a statistically-valid probability design stratified to allow estimates of the condition of streams on a national and regional scale. The two key questions the WSA addresses are

- To what degree are the Nation's wadeable streams in good, fair, and poor condition?
- What is the relative importance of the different stressors evaluated in the WSA?

The WSA is a collaboration among the U.S. Environmental Protection Agency (EPA), states, tribal nations, U.S. Geological Survey (USGS), and other partners. It is intended as a document for the public and Congress. It is not a technical document, but rather a report geared towards a broad audience, some with little or scientific background. This Technical Addendum is a supplemental document used to support the results in the WSA report. It describes the process used to collect, evaluate, and analyze data for the WSA. It outlines steps taken to assess the biological condition of the nation's freshwater resources and identify the relative impact of stressors on this condition. Results from the analysis are included in this 2006 WSA Report; the data collected and methods described will continue to be studied and used for future analyses.

The WSA data analysis procedures described in this addendum were developed from the input and experience of the participating cooperators and technical experts. Two small workgroups were held in the fall of 2005 to consider approaches for data analysis. Findings from these workshops were presented to a larger group of cooperators at the Wadeable Streams National Meeting in January 2006. Here, state agencies, universities, non-profits, EPA, and other federal agencies participated in a number of small breakout sessions where they discussed topics such as analysis options, data presentation, and reference sites. Discussions from these meetings were used to define the steps taken for the data analysis presented in the final report.

Reference Condition

To assess current ecological condition, it is necessary to compare measurements today to an estimate of expected measurements in a less-disturbed situation. Setting reasonable expectations for each indicator was one of the greatest challenges for the WSA. Because of the difficulty in estimating historical conditions for many WSA indicators, the 2006 WSA used "least-disturbed condition" as the reference condition. Least-disturbed condition can be defined as the best available chemical, physical, and biological habitat conditions given the current state of the landscape. Reference criteria describe the sites whose condition is "the best of what's left." Data from reference sites were used to develop the ecoregionally specific reference conditions against which test results could be compared.

Sources of Reference Sites

The reference sites used in the WSA came from two major sources:

1. Sites sampled during the WSA using consistent sampling protocols and analytical methods that were screened to meet ecoregional specific physical and chemical criteria. These included both sites selected randomly from the probability sample and sites hand-picked to be reference by best professional judgment and sampled using WSA methods as part of the WSA. For example, in the Eastern United States, states submitted 10 of their best reference sites to be sampled as part of the WSA.
2. Sample data provided by other agencies, universities, or states from sites that were deemed to be suitable as reference sites by best professional judgment. Based on recommendations from a technical workgroup and preliminary comparability work, external sources of reference sites were incorporated into the analysis portion of the assessment. These sites were either sampled with the same methodology as the WSA or had field and lab protocols with enough similarities that the data analysis group felt the data were comparable.

Screening WSA Site Data for Reference Condition

To identify reference sites for purposes of the WSA, we used the chemical and physical data we collected at each site (e.g., nutrients, turbidity, acidity, riparian condition) to determine whether any given site is in least-disturbed condition for its ecoregion. In the WSA, nine physical and chemical parameters were used to screen for reference sites, total nitrogen, total phosphorus, chloride, sulfate, acid-neutralizing capacity, turbidity, rapid habitat assessment score, percent fine substrate, and riparian disturbance index. If a site exceeded the screening value for any one stressor, it was dropped from reference consideration. Given that expectations of least-disturbed condition vary across ecoregions, the criteria values for exclusion varied by ecoregion. The nine aggregate level III ecoregions developed for the WSA were used regionalize reference conditions (Table A-1). All sites in the WSA (both probability and hand-picked) that passed all criteria were considered to be reference sites for the WSA.

Table A-1. Macroinvertebrate Reference Sites

Ecoregion	Data Source		Total
	External	WSA	
Northern Appalachians (NAP)	114	27	141
Southern Appalachians (SAP)	354	35	389
Coastal Plains (CPL)	98	15	113
Upper Midwest (UMW)	68	12	80
Temperate Plains (TPL)	124	38	162
Northern Plains (NPL)	10	18	28
Southern Plains (SPL)	56	21	77
Western Mountains (WMT)	335	129	464
Xeric (XER)	132	39	171
Total	1,291	334	1,625

Note that the WSA did not use data on landuse in the watersheds for this purpose—sites in agricultural areas (for example) may well be considered least disturbed, provided that their chemical and physical conditions are among the best for the region. Additionally, the WSA did not use data on the biological assemblages themselves because these are the primary components of the stream and river ecosystems being evaluated and to use them would constitute circular reasoning.

Data Supplied from External Sources

Ideally, WSA investigators would have used reference sites picked in a consistent manner and sampled with identical protocols in all analyses. However, macroinvertebrate assessments require a large number of reference sites; more were available by screening WSA sites as described in Chapter 2.1.1. Many other investigators have used reference sites in their analyses. The WSA project team compiled a set of macroinvertebrate reference site data from external sources focusing on regions of the country where reference site data were limited. The major sources of supplemental macroinvertebrate data were the following:

- State agency data
- USGS National Ambient Water Quality Assessment (NAWQA) data
- Utah State University STAR grant data
- Earlier EPA Environmental Monitoring and Assessment Program (EMAP) and Regional Environmental Monitoring and Assessment Program (REMAP) data.

To be included in the WSA analyses, these data had to meet the following standards of macroinvertebrate sampling and laboratory analysis:

- A multi-habitat sampling method
- A minimum 300 organism lab count
- A minimum of genus level identification of insects, including Chironomids.

Sites incorporated from the external sources had varying levels of similarity to the WSA. Reference sites from the EPA EMAP and REMAP studies were sampled using the same methodologies as the WSA. Utah State University received a STAR grant to identify and sample reference sites in the western states using the same methodologies as the WSA. Because both of these sources of reference sites were sampled using the same methodologies, they are considered highly comparable to the WSA. A comparability study done on USGS NAWQA sites and WSA methods in high-gradient streams showed the results of the two methods were comparable in these high-gradient stream areas. USGS NAQWA sites from low-gradient streams were not included because of differences in methods. Sites from state agencies had to meet the previously mentioned criteria to be incorporated into the assessment. These sites were considered comparable based on best professional judgment of the technical workgroups and feedback from the national WSA meeting. It was not possible to screen the data, for example, for physical or chemical criteria; as such comprehensive data were not available for all these sites. The resulting reference site database had macroinvertebrate data from 1,625 sites, 334 WSA sites, and 1,291 external source sites.

Benthic Macroinvertebrate Assemblage

The taxonomic composition and relative abundance of different taxa that compose the benthic macroinvertebrate assemblage present in a stream have been used extensively in North America, Europe, and Australia to assess how human activities affect ecological condition (Barbour et al., 1995, 1999; Karr and Chu 1999). Two principal types of ecological indicators to assess condition based on benthic macroinvertebrates are currently prevalent: multimetric index and predictive models of taxa richness. The purpose of these indicators is to present the complex data represented within an assemblage in a way that is understandable and informative to resource managers and the public. Both approaches were recommended for use in the WSA by cooperators and participants at the WSA national meeting. The following chapters provide a general overview of the approaches used to develop ecological indicators based on benthic macroinvertebrate assemblages, followed by details regarding data preparation and the process used for each approach to arrive at a final indicator.

Overview: Macroinvertebrate Index and O/E Predictive Model Approaches

Multimetric indicators have been used in the United States to assess condition based on fish and macroinvertebrate assemblage data (e.g., Karr and Chu, 1999; Barbour et al., 1999; Barbour et al., 1995). The multimetric approach involves summarizing various assemblage attributes (e.g., composition, tolerance to disturbance, trophic and habitat preferences) as individual "metrics" or measures of the biological community. Candidate metrics are then evaluated for various aspects of performance, and a subset of the best performing metrics are combined into an index, typically referred to as a Macroinvertebrate Index of Biotic Condition (Macroinvertebrate Index).

The predictive model approach was initially developed in Europe and Australia and is becoming more prevalent within the United States. The approach estimates the expected taxonomic composition of an assemblage in the absence of human stressors (Hawkins et al., 2000; Wright, 2000), using a set of least-disturbed sites and other variables related natural gradients (e.g., elevation, stream size, stream gradient, latitude, longitude). The resulting models are then used to estimate the expected taxa composition (expressed as taxa richness) at each stream site sampled. The number of expected taxa actually observed at a site is compared to the total number of expected taxa as an Observed Expected ratio (O/E index). Departures from a ratio of 1.0 indicate that the taxonomic composition in a stream sample differs from that expected under least-disturbed conditions.

Data Preparation: Standardizing Counts

The number of individuals in a sample was standardized to a constant number to provide an adequate number of individuals that was the same for nearly all samples and that could be used for both multimetric index development and O/E predictive modeling index. A subsampling technique involving random sampling without replacement was used to extract a true "fixed count" of 300 individuals from the total number of individuals enumerated for a sample (target count = 500 individuals).

Samples that did not contain at least 300 individuals were reviewed and retained for further analysis when appropriate (i.e., if the sampling effort was determined to be sufficient) because low counts can indicate a response to one or more stressors. For samples from sites classified as least disturbed, those with at least 250 individuals were retained.

Operational Taxonomic Units

To provide a nationally consistent database for the macroinvertebrates, taxonomic listings were reviewed for discrepancies. In some cases it was necessary to combine taxa to a coarser level of common taxonomy. This new combination of taxa is called the "Operational Taxonomic Unit" or OUT and improves the level of confidence in an overall assessment.

Autecological Characteristics

Autecological characteristics refer to specific ecological requirements or preferences of a taxon for habitat preference, feeding behavior, general behavior, and tolerance to human disturbance. These characteristics are prerequisites for the Macroinverbrate Index, which incorporates various ecological attributes into its framework. A number of state/regional organizations and research centers have developed autecological characteristics for benthic macroinvertebrates in their region. For the WSA, a consistent national list of characteristics that consolidated and reconciled any discrepancies among the regional lists was developed and calibrated for use in a Macroinvertebrate Index.

Members of the data analysis group pulled together autecological information from five existing sources: the EPA Rapid Bioassessment Protocols document, the NAWQA national and northwest lists, the Utah State University list, and the EMAP Mid-Atlantic Highlands (MAHA) and Mid-Atlantic Integrated Assessment (MAIA) list. These five were chosen because they were thought to be the most independent of each other and the most inclusive taxa. A single national-level list was developed based on the decision rules outlined below.

Tolerance Values

Tolerance value assignments followed the convention for macroinvertebrates, ranging between 0 (least tolerant or most sensitive) to 10 (most tolerant). For each taxon, tolerance values from all five sources were reviewed, and a final assignment was made according to the following rules:

- If values from different lists were all < 3 (sensitive), final value = mean;
- If values from different lists were all > 3 and < 7 (facultative), final value = mean;
- If values from different lists were all > 7 (tolerant), final value = mean;
- If values from different lists spanned sensitive, facultative, and tolerant categories, best professional judgement was used, along with alternative sources of information (if available) to assign a final tolerance value;
- Tolerance values of 0–3 were considered "sensitive"; values of 8–10 were considered "tolerant"; and values of 4–7 were considered "facultative."

Functional Feeding Group and Habit Preferences

In most cases, there was a high agreement among the five data sources. When discrepancies in functional feeding group (FFG) or habit preference assignments among the five primary data sources were identified, a final assignment was made based on the most prevalent assignment. In cases where there was no prevalent assignment, the workgroup examined why disagreements existed, flagged the taxon, and used best professional judgment to make the final assignment.

Macroinvertebrate Index Development

Two alternative approaches to developing a Macroinvertebrate Index for the WSA were evaluated. The first alternative was to develop separate, yet coordinated, Macroinvertebrate Indexes for each of the nine assessment regions. This approach recognizes the potential need for metrics to be selected and scored separately by region, but uses a single evaluation and scoring process so that the individual regional indexes can be combined into a single assessment without introducing regional bias. Each regional Macroinvertebrate Index was composed of a core set of metrics that performed best in that region.

The second alternative was to develop a single, universal index for the entire WSA study area. The universal Macroinvertebrate Index consisted of a single set of core metrics that performed adequately across all regions, but addressed regional biases by scoring metrics separately by assessment region, and used different thresholds in each assessment region to identify least-disturbed versus most- disturbed condition. After evaluating the results from both approaches, the regionally specific Macroinvertebrate Indexes were better able to discriminate least- disturbed from most-disturbed sites; therefore, the regional indexes were used to assess ecological condition for the WSA.

Metric Evaluation and Selection

Candidate metrics were derived from the benthic invertebrate count data and the autecological characteristics of each taxon. In most cases, three variants of each candidate metric were calculated: one based on taxa richness, one based on the proportion of individuals, and one based on the proportion of taxa. All candidate metrics were assigned to one of the following six categories representing different aspects of biotic integrity (Barbour et al., 1999; Karr, 1993; Karr et al., 1986; Stoddard et al., 2005)

- **Richness:** The number of different kinds of taxa.

- **Diversity:** Evenness of the distribution of individuals across taxa.
- **Composition:** The relative abundance of different kinds of taxa.
- **Functional feeding groups:** The Primary method for acquiring food.
- **Habit:** The habitat preference or dominant behavior, i.e., do taxa cling to substrates, or burrow into substrates?
- **Tolerance:** Often expressed as a general tolerance to stressors.

A series of performance evaluations was conducted to identify the best metric from each metric category. The evaluations were applied sequentially and by assessment region. Candidate metrics that failed a test were eliminated from additional consideration and testing.

- **Range test:** Candidate metrics that have a small (or narrow) range, or where most of the values are identical, are not likely to provide information that helps differentiate among sites. Richness metrics were eliminated if their range was less than 4. Proportional metrics having a range ≤ 0.1 were retained, but were considered to be poor performers. Metrics having more than 75% of the values the same were also eliminated.
- **Signal to noise (S:N) test:** "Signal to noise" is the ratio of variance among sites and the variance within a site (based on repeated visits to the same site). A low S:N value indicates a metric that cannot distinguish among sites very well. S:N ratios were calculated for each assessment region. Generally, candidate metrics having S:N values ≤ 1 were eliminated.
- **Responsiveness:** Responsiveness to disturbance was evaluated using standard statistical technique, an F-test, to determine if the mean metric values for least-disturbed and most-disturbed sites were statistically equivalent or distinct. Candidate metrics with F ≤ 1 were eliminated.

Candidate metrics that passed all of the above tests were sorted by F values. Selection of the final metrics for inclusion in a Macroinvertebrate Index was conducted separately for each assessment region. The metric with the highest F value was selected first. The metric having the next highest F value that was from a different metric category was then selected. This process was repeated until one metric from all 6 metric categories was selected. As a final test, the selected metrics were evaluated for redundancy.

- **Redundancy:** Only metrics that did not contain redundant information were included in the final indexes. Inclusion of redundant metrics adds little information to the Macroinvertebrate Index, and may bias the index. We evaluated redundancy by using only the set of least-disturbed sites to avoid eliminating metrics that are correlated only because of their relationship to stressors that co-vary. A pairwise correlation analysis was conducted. Metrics having a Pearson correlation coefficient (r) >0.71 were considered to be redundant. This value of r corresponds to a coefficient of determination (r2) value of 0.5.

For each metric pair that was redundant, the metric selected for inclusion first (i.e., with the higher F value) was retained. The redundant metric was replaced with the metric from the same metric category that had the highest F value and was non-redundant.

Using the approach described above, final metrics selected for the regional Macroinvertebrate Indexes are shown in Table A-2.

Table A-2. Metrics used by ecoregion and nationally for the Macroinvertebrate Index

Final metrics selected for the regional Macroinvertebrate Indices were:

Metric	NAP	SAP	CPL	UMW	TPL	NPL	SPL	WMT	XER
EPT % Taxa	X					X		X	
EPT % Individuals					X		X		
Non-Insect % Individuals			X						X
Ephemeroptera % Taxa		X							
Chironomid % Taxa				X					
Shannon Diversity		X	X	X	X	X	X		
% Individuals in Top 5 Taxa	X							X	X
Scraper Richness	X	X			X	X	X	X	X
Shredder Richness			X	X					
Burrower % Taxa		X		X		X	X		
Clinger % Taxa	X		X					X	X
Clinger Richness					X				
Ephemeroptera Richness					X	X			
EPT Richness	X	X	X	X			X	X	X
Intolerant Richness							X		
Tolerant % Taxa		X	X					X	X
Hillsenhoff Biotic Index									
PTV 0-5.9 Richness						X			
PTV 0-5.9% Taxa	X								
PTV 8-10% Taxa				X	X				

Metric Scoring and Macroinvertebrate Index Calculation

Before being combined into an Macroinvertebrate Index, each metric was scored to translate results to a single scale (a continuous scale ranging from 0 to 10). For each regional index, each of the six metrics was scored separately by assessment region using a scheme intended to maximize differences in final index scores (Blocksom, 2003). Scoring was based on the distribution of metric values of all sites sampled. For metrics having the highest values at least-disturbed sites, values less than the 5th percentile were scored as 0 (floor value), while those with values equal to or greater than the 95th percentile were scored as 10 (ceiling value). All metric values in between were assigned a score based on a linear interpolation between the ceiling and floor values. For metrics having the highest values at most-disturbed sites, values less than the 5th percentile were scored as 10, while values greater than or equal to the 95th percentile were scored as 0. The final Macroinvertebrate Index score was calculated by first summing the six metric scores. This total was then scaled to range from 0 to 100 by multiplying it by 1.666.

The regional indexes were evaluated by calculating a S:N ratio and F value as described in Chapter 3.3.1.

Modeling of Macroinvertebrate Index Condition class thresholds for the WSA

Previous large-scale assessments have converted Macroinvertebrate Index scores into classes of assemblage condition by comparing those scores to the distribution of scores observed at least-disturbed reference sites. If a site's index score was less then the 5th percentile of the reference distribution, it was classified as most-disturbed condition; those scores between the 5th and 25th percentile were classified as intermediate disturbance; and scores greater than the 25th percentile were classified as least-disturbed condition. This approach assumes that the distribution of index scores at reference sites reflects an approximately equal, minimum level of human disturbance across those sites. But this assumption did not appear to be valid for some of the nine assessment regions, which was confirmed by state and regional bioloigsts at meetings to review the draft results. When reviewing references sites, the variation in the quality of references between the individual regions indicates that the thresholds drawn using these reference conditions set unequal bars across the nation. Regions with high-quality reference sites had more stringent thresholds than regions with disturbed reference sites.

For the WSA, the project team performed a principal components analysis (PCA) of nine habitat and water chemistry variables that had originally been used to select Macroinvertebrate Index reference sites. The first principal component (Factor 1) of this PCA represented a generalized gradient of human disturbance. Index scores were weakly, but significantly, related to this disturbance gradient in five of the nine aggregate regions (Figure A-1), contrary to the assumption of approximately equal disturbance levels. Thus, index reference distributions from these regions are biased downward because they include somewhat disturbed sites that have low index scores, unless we account for this in the process of setting thresholds.

The regression models in Figure A-1 were used to adjust the Macroinvertebrate Index reference distributions in the five regions (Southern Appalachians [SAP], Temperate Plains [TPL], Northern Plains [NPL], Southern Plains [SPL], Western Mountains [WMT]) to reflect only the better reference conditions within a region, as indicated by lower disturbance scores (PCA Factor 1 scores). Figure A-2 explains the adjustment method and illustrates the method for the Western Mountains region. Following distribution adjustments, the Least/Intermediate and Intermediate/Most disturbed class thresholds for each region were defined by the 5th and 25th percentiles of that region's adjusted index distribution, as illustrated in Figure A-2. Macroinvertebrate Index threshold values can be found in Table A-3.

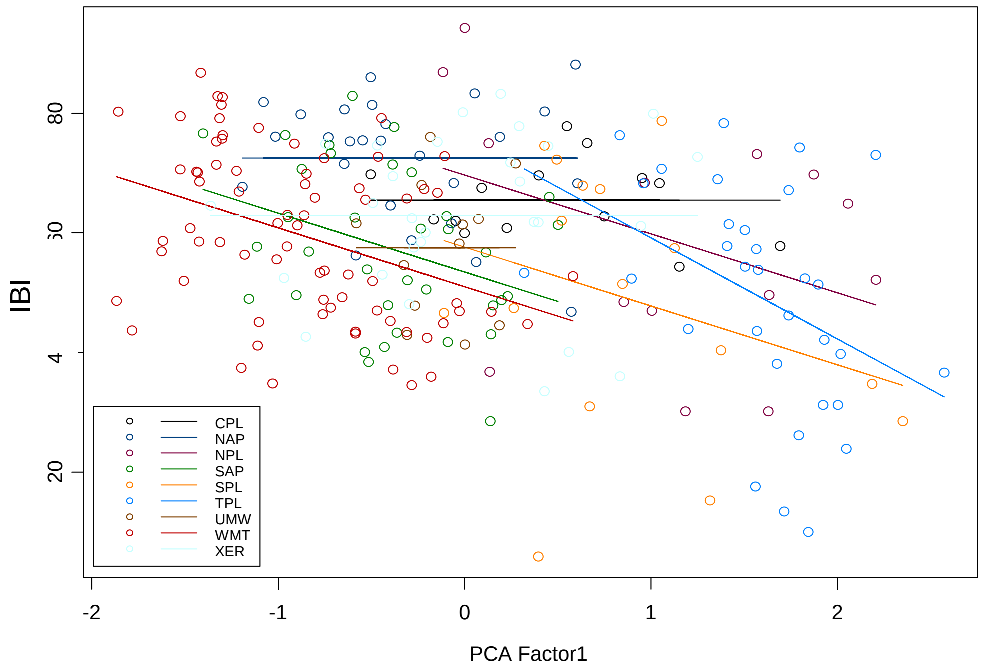

Figure A-1. Scatterplot and regression models of Macroinvertebrate Index versus PCA Factor 1 scores at reference sites, by region. Horizontal lines denote regions with no significant relationship.

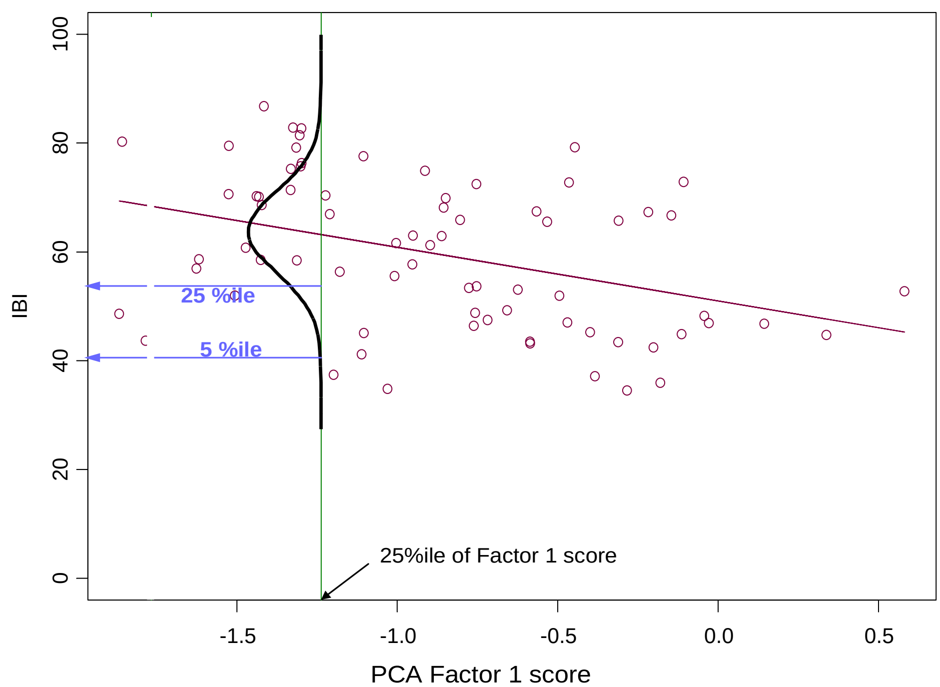

Figure A-2. Adjusting the Macroinvertebrate Index reference distribution and setting class thresholds for the Western Mountains (WMT) region. Points denote Macroinvertebrate Index and Factor 1 scores at all WMT reference sites; the line is a linear regression on those points. We assumed that index scores at a subset of the "better" reference sites would be normally distributed, with a mean value predicted by the regression from the 25th percentile of the PCA Factor 1 score.

The distribution's standard deviation is estimated by the pooled residual standard deviation obtained from regressions in all regions. Macroinvertebrate Index disturbance class thresholds (41 and 55) are given by the 5th and 25th percentile of the distribution at better reference sites.

Table A-3. Threshold values for the nine regional Macroinvertebrate Indexes.

Region	Least-Disturbed/ Intermediate	Intermediate/ Most-Disturbed
CPL	56	42
NAP	63	49
NPL	62	49
SAP	56	42
SPL	50	36
TPL	52	38
UMW	48	34
WMT	59	45
XER	53	40

O/E: Predictive (RIVPACS) Models

The second method used to assess ecological condition for the WSA was a predictive O/E model. The O/E model compares the observed benthic assemblage at a site to an expected assemblage derived from a population of reference sites. Stressors and anthropogenic impacts lead to a reduction in the number of taxa that are expected to be present under reference conditions. The predictive model approach is used by several states and is a primary assessment tool of Great Britain and Australia.

The O/E ratio predicted by the model for any site expresses the number of taxa found at that site (O), as a proportion of the number that would be expected (E) if the site was in least-disturbed condition. Ideally, a site in reference condition has an O/E = 1.0. An O/E value of 0.70 indicates that 70% of the expected taxa at a site were actually observed at the site. This is interpreted as a 30% loss of taxa relative to the site's predicted reference condition. However, O/E values vary among reference sites themselves, around the idealized value of 1.0, because such sites rarely conform to an idealized reference condition and because of model error and sampling variation. The standard deviation of O/E (Table A-4) indicates the breadth of O/E variation at reference sites. Thus, the O/E value of an individual site should not be interpreted as (1 – taxa loss) without taking account of this variability in O/E. Individual O/E values are most reliably interpreted relative to the entire O/E distribution for the reference sites.

A nationally-distributed collection of reference sites was first identified, drawn from a pool of sites whose macroinvertebrates were sampled using EMAP protocols. This pool included only WSA, EMAP-West, STAR-USU, USGS NAWQA, and MAHA/MAIA sites. Twenty percent of all reference sites were set aside to validate the models, and the remaining 80% were used to calibrate the models (Table A-4). Each site contributed a single sampled macroinvertebrate assemblage to model calibration and validation. Each sampled macroinvertebrate assemblage comprising more than 300 identified individuals was randomly subsampled to yield 300 individuals. These 300-count subsamples were used to build models and assess all WSA sites.

The predictive modeling approach assumes that expected assemblages vary across reference sites throughout a region due to natural (nonanthropogenic) environmental features such as geology, soil type, elevation, and precipitation. To model these effects, the approach first classifies reference sites based on similarities of their macroinvertebrate assemblages (Table A-4). A discriminant function model is then built to predict the membership of any site in these classes, using natural environmental features as predictor variables (Table A-4). The predicted occurrence probability of a reference taxon at a site is then predicted to be the weighted average of that taxon's occurrence frequencies in all reference site classes, using the site's predicted group membership probabilities in the classes as weights. Finally, E for any site is the sum, over a subset of reference taxa, of predicted taxon occurrence probabilities, whereas O is the number of taxa in that subset that were observed to be present at the site. The subset of reference taxa used for any site was defined as those taxa with predicted occurrence probabilities exceeding 0.5 at that site.

Final predictive models performed better than corresponding null models (no adjustment for natural-factor effects), as judged by their smaller standard deviation of O/E across calibration sites (Table A-4).

Similar to the Macroinvertebrate Index, two scaled approaches were used to develop the O/E model. A national model was initially developed to predict taxa loss at sites, and three models were developed for WSA usage, together covering the conterminous United States (Table A-4). The regional models performed better and were used in the WSA to predict taxa loss at the sites.

The three final regional models were applied to estimate O/E for 1354 WSA sites that were sampled for benthic macroinvertebrates, depending on each site's regional location. Predictions could not be made for 36 WSA sites because the predictor data was either missing or outside the model's experience.

Table A-4. WSA predictive models.

Model Name	Eastern Highlands	Plains and Lowlands	West
Regions covered	NAP, SAP	CPL, UMW, TPL, NPL, SPL	WMT, XER
Number of calibration sites	193	138	519
Number of validation sites	43	40	123
Number of site classes	11	11	31
Discriminant function predictor variables	Site longitude, mean of minimum annual temperature, mean number of wet days per year, watershed area, Julian day of sampling	Julian day of sampling, elevation, mean number of frost-free days per year, mean annual precipitation, watershed area, stream gradient	Site longitude, Julian day of sampling, watershed area, mean annual precipitation, mean of minimum annual temperature, elevation, stream gradient
Standard deviation of O/E at calibration sites: Predictive model Null model	 0.16 0.21	 0.27 0.29	 0.19 0.26

Physical Habitat Condition Assessment

An assessment of stream physical habitat condition was a major component of the WSA. Of many possible general and specific stream habitat indicators measured in the WSA (see Kaufmann et al., 1999), the WSA chose streambed excess fine sediments, habitat cover complexity, riparian vegetation, and riparian human disturbances in this assessment. These four indicators are generally important throughout the United States. Furthermore, the project team had reasonable confidence in factoring out natural variability to determine expected values and the degree of anthropogenic alteration of the habitat attributes represented by these indicators.

Streambed Sediments

Streambed characteristics (e.g., bedrock, cobbles, silt) are often cited as major controls on the species composition of macroinvertebrate, periphyton, and fish assemblages in streams (Hynes, 1972; Cummins, 1974; Platts et al., 1983; Barbour et al., 1997). Along with bedform (e.g., riffles and pools), streambed particle size influences the hydraulic roughness and, consequently, the range of water velocities in a stream channel. It also influences the size range of interstices that provide living space and cover for macroinvertebrates and smaller vertebrates. Accumulations of fine substrate particles (excess fine sediments) fill the interstices of coarser bed materials, reducing habitat space and its availability for benthic fish and macroinvertebrates (Platts et al., 1983; Hawkins et al., 1983l; Rinne, 1988). In addition, these fine particles impede circulation of oxygenated water into hyporheic habitats. Streambed characteristics are often sensitive indicators of the effects of human activities on streams (MacDonald et al., 1991; Barbour et al., 1997). Decreases in the mean particle size and increases in streambed fine sediments can destabilize stream channels (Wilcock, 1997; Wilcock, 1998) and may indicate increases in the rates of upland erosion and sediment supply (Lisle, 1982; Dietrich et al., 1989).

Unscaled measures of surficial streambed particle size, such as percent fines or D_{50}, can be useful descriptors of streambed conditions. In a given stream, increases in percent fines or decreases in D_{50} may result from anthropogenic increases in bank and hillslope erosion. However, a great deal of the variation in bed particle size we see among streams is natural— the result of differences in stream or river size, slope, and basin lithology. The power of streams to transport progressively larger sediment particles increases in direct proportion to the product of flow depth and slope. Steep streams tend to have coarser beds than similar sized streams on gentle slopes. Similarly, the larger of two streams flowing at the same slope will tend to have coarser bed material because the deeper flow has more power to scour and transport fine particles downstream (Leopold et al., 1964; Morisawa, 1968). For these reasons, we "scale" bed particle size metrics, expressing bed particle size in each stream as a deviation from that expected as a result of its size, power, and landscape setting. Relative Bed Stability (RBS) is a scaled-bed particle size metric and is the metric that is used to determine the streambed sediment indicator for the WSA.

Although many human activities directly or indirectly alter the size of streambed material, bed particle sizes also vary naturally in streams with different drainage areas, slopes, and surficial geologies (Leopold et al., 1964; Morisawa, 1968). The particle size composition of a streambed depends on the rates of supply of various sediment sizes to the stream and the rates at which the flow takes them downstream (Mackin, 1948). Topography, precipitation, and land cover influence sediment supply to streams, but the source of sediments is the basin soil and geology, and supplies are greater where these materials are inherently more erodible. Once sediments reach a channel and become part of the streambed, their transport is largely a function of channel slope and discharge during floods (in turn, discharge is largely dependent upon drainage area, precipitation, and runoff rates). However, a stream or river's competence and capacity to transport sediments can be greatly altered by the presence of such features as large woody debris and complexities in channel shape (e.g., sinuosity, pools, changes in width/depth ratio). The combination of these factors determines the depth and velocity of streamflow and the shear stress (erosive force) that it exerts on the streambed. The streambed sediments indicator used in the WSA to evaluate bed stability and streambed excess fine sediments compares the actual particle sizes observed in a streambed with a calculation of the sizes of particles that can be mobilized by that stream. Values of streambed sediments lower than reference expectations generally indicate excess fine sediments from soil erosion, although unstable streambeds can also result from hydrologic alteration that increases the size or frequency of floods. Values of streambed sediments higher than reference expectations can indicate anthropogenic coarsening or armoring of streambeds, but streams containing substantial amounts of bedrock may also have very high streambed sediments score. At this time, it is difficult to determine the role of human alteration in stream coarsening on a national scale. For this reason, we currently report only on the "low end" of streambed sediments relative to reference conditions, generally indicating streambed sediments associated with human disturbance of stream drainages and riparian zones.

Many researchers have scaled observed stream reach or riffle particle size (e.g., median diameter D_{50}, or geometric mean diameter D_{gm}) by the calculated mobile, or "critical" bed particle diameter (D_{cbf}), in the stream channel. The scaled median streambed particle size is expressed as Relative Bed Stability (RBS), calculated as the ratio D_{50}/D_{cbf} (Dingman, 1984; Gordon et al., 1992), where D_{50} is based on systematic streambed particle sampling ("pebble counts") and D_{cbf} is based on the estimated streambed shear stress at bankfull flows. Kaufmann et al. (1999) modified the calculation of D_{cbf} to incorporate large wood and pools, which can greatly reduce shear stress in complex natural streams. They also formulated the calculation of both D_{gm} and D_{cbf} so that RBS could be estimated from physical habitat data obtained from large-scale regional ecological surveys such as WSA. RBS is quantified as the ratio of observed bed surface particle diameter divided by the "critical" or mobile particle diameter calculated for a given streamflow condition (Dingman, 1984). It is the inverse of the streambed "fining" measure calculated by Buffington and Montgomery (1999a; 1999b), and is conceptually similar to the "Riffle Stability Index" of Kappesser (2002) and the bed stability ratio discussed by Dietrich et al. (1989).

When evaluating the stability of whole streambeds (vs. individual bed particles), observed substrate is typically represented by the median surface particle diameter (e.g., D_{50}) or the geometric mean diameter (D_{gm}). To characterize the actual substrate particle size distribution in a stream channel, WSA field protocols followed the widely accepted procedure (e.g., Platts et al., 1983; Bauer and Burton, 1993) of employing a systematic "pebble count," as described by Wolman (1954). Observed bed particle size was calculated as the geometric mean particle diameter from systematic "pebble counts" of 105 particles along the stream bed.

To calculate critical (mobile) bed particle diameter in a natural stream, it is necessary to estimate average streambed tractive force, or shear stress, for establishing a common reference flow condition likely to mobilize the streambed. Bankfull discharge is typically chosen for this purpose because the shear stress under these conditions can be estimated from field evidence observed during low flow in most regions. Bankfull flows are large enough to erode the stream bottom and banks, but frequent enough (return interval of one to two years) not to allow substantial growth of upland terrestrial vegetation (Harrelson et al., 1994; Kaufmann et al., 1999). Consequently, in many regions, it is these flows that have determined the width and depth of the channel, so the depth of one- to two-year floods can be approximated from the depth of the bankfull channel when evaluated in the field at low flow (Dunne and Leopold, 1978; Leopold, 1994). The WSA approach for estimating the critical diameter for bed particles in a stream is based on sediment transport theory (Simons and Senturk, 1977). This establishes an estimate of the average streambed shear stress or erosive tractive force on the bed during bankfull flow, based on quantitative estimates of bankfull flow depth, slope, channel shape, and roughness. Stream channels can be very complex, exhibiting a wide range in local bed shear stress due to small-scale spatial variation in slope, depth, and roughness within a channel reach (Lisle et al., 2000). The influence of large-scale channel roughness can be very important in determining bed stability, so we modified Dingman's (1984) RBS formulation to accommodate losses in shear stress resulting from large woody debris and channel complexity (Kaufmann et al., 1999; Kaufmann et al., in preparation). These roughness elements reduce shear stress and, therefore, critical diameter in streams flowing at a given depth and slope. Compared with simple or hydraulically "smooth" channels, shear stress is reduced in streams with large roughness elements, thereby increasing the stability of fine particles.

Finally, we calculated RBS as the reach-wide geometric mean substrate diameter divided by the bankfull critical diameter (RBS = D_{gm}/ D_{cbf}), typically expressing it as the WSA variable LRBS_bw5, which is Log_{10} (RBS). Similarly, Log_{10} (RBS)=$Log_{10}(D_{gm})$ – $Log_{10}(D_{cbf})$. The equivalent formula, expressed in WSA variables is LRBS_bw5= LSUB_dmm – LDMB_bw5.

In interpreting RBS on a regional scale, Kaufmann et al. (1999) argued that, over time, streams and rivers adjust sediment transport to match supply from natural weathering and delivery mechanisms driven by the natural disturbance regime. This indicates that RBS in appropriately stratified regional reference sites should be evaluated in a range characteristic of the climate, lithology, and natural disturbance regime.

Values of the RBS Index that are either substantially lower (finer, more unstable streambeds) or higher (coarser, more stable streambeds) than those expected based on the range found in least-disturbed reference sites within an ecoregion are considered to be indicators of ecological stress. Excess fine sediments can destabilize streambeds when the supply of sediments from the landscape exceeds the ability of the stream to move them downstream. This imbalance results from numerous human uses of the landscape, including agriculture, road building, construction, and grazing. Lower than expected streambed stability may result either from high inputs of fine sediments (erosion) or increases in flood magnitude or frequency (hydrologic alteration). When low RBS results from fine sediment inputs, stressful ecological conditions result from fine sediments filling in the habitat spaces between stream cobbles and boulders.

In-stream Fish Habitat

The most diverse fish and macroinvertebrate assemblages are found in streams and rivers that have complex forms of habitat, including large wood, boulders, undercut banks, and tree roots. When other needs are met, complex habitat with abundant cover should generally support greater biodiversity than simple habitats that lack cover (Gorman and Karr, 1978; Benson and

Magnuson, 1992). Human use of streams and riparian areas often results in the simplification of this habitat, with potential effects on biotic integrity.

In-stream fish habitat is difficult to quantify. For this assessment, we use a measure (XFC_NAT in Kaufmann et al., 1999) that sums the amount of in-stream habitat consisting of undercut banks, boulders, large pieces of wood, brush, and cover from overhanging vegetation within a meter of the water surface, all of which are estimated visually by WSA field crews. The WSA Physical Habitat protocols provide estimates for nearly all of the following components of complexity identified during EPA's 1992 stream monitoring workshop (Kaufmann, 1993):

- Habitat Type and Distribution (e.g., Bisson et al., 1982; O'Neill and Abrahams, 1984; Frissell et al., 1986; Hankin and Reeves, 1988; Hawkins et al., 1993; Montgomery and Buffington, 1993, 1997, 1998).
- Large Woody Debris count and size (e.g., Harmon et al., 1986; Robison and Beschta, 1990).
- In-Channel Cover: Percentage areal cover of fish concealment features, including undercut banks, overhanging vegetation, large woody debris, and boulders (Hankin and Reeves, 1988; Kaufmann and Whittier, 1997)
- Residual pools, channel complexity, and hydraulic roughness (e.g., Lisle, 1992; Lisle, 1987; Kaufmann, 1987a; Kaufman, 1987b; Robison and Kaufmann, 1994)
- Width and depth variance and bank sinuosity (Kaufmann 1987a; Moore and Gregory, 1988; Madej, 2001;).

In-stream fish habitat and the abundance of particular types of habitat features differ naturally with stream size, slope, lithology, flow regime, and potential natural vegetation. For example, boulder cover will not occur naturally in streams draining deep deposits of loess or alluvium that do not contain large rocks. Similarly, large wood will not be found naturally in streams located in regions where riparian or upland trees do not grow naturally. Though the combined cover index XFC_NAT partially overcomes these differences, we set stream-specific expectations for habitat complexity metrics based on region-specific reference sites.

Riparian Vegetative Cover

The importance of riparian vegetation to channel structure, cover, shading, nutrient inputs, large woody debris, wildlife corridors, and as a buffer against anthropogenic disturbance is well recognized (Naiman et al., 1988; Gregory et al., 1991). Riparian vegetative cover not only moderates stream temperatures through shading, but also increases bank stability and the potential for inputs of coarse and fine particulate organic material. Organic inputs from riparian vegetation become food for stream organisms and provide structure that creates and maintains complex channel habitat.

The presence of a complex, multi-layered vegetation corridor along streams and rivers is a measure of how well the stream network is buffered against sources of stress in the watershed. Intact riparian areas can help reduce nutrient and sediment runoff from the surrounding landscape, prevent bank erosion, provide shade to reduce water temperature, and provide leaf litter and large wood that serve as food and habitat for stream organisms. The presence of canopy trees in the riparian corridor indicates 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.

For the WSA, we evaluated the cover and complexity of riparian vegetation based the metric XCMGW, which is calculated from visual estimates of the areal cover and type of vegetation in three layers (the ground layer, woody shrubs, and canopy trees) made by WSA field crews. XCMGW is a combined measure of the cover of woody vegetation summed over the three vegetation layers, giving an indication of the abundance of vegetation cover and its structural complexity. Its theoretical maximum is 3.0 if there is 100% cover in each of the three vegetation layers. The separate measures of large and small diameter trees, woody and non-woody mid-layer vegetation, and woody and non-woody ground cover were all visual estimates of areal cover. XCMGW gives an indication of the longevity and sustainability of perennial vegetation in the riparian corridor (Kaufmann et al, 1999).

Riparian Disturbance

Agriculture, buildings, and other evidence of human activities in the stream channel and its riparian zone may, in themselves, serve as indicators of habitat quality. They may also serve as diagnostic indicators of anthropogenic stress. EPA's 1992 stream monitoring workshop recommended field assessment of the frequency and extent of both in-channel and near-channel human activities and disturbances (Kaufmann, 1993). In-channel disturbances include channel revetment, pipes, straightening, bridges, culverts, and trash. Near-channel riparian disturbances include buildings, lawns, roads, pastures, orchards, and row crops. The vulnerability of the stream network to potentially detrimental human activities increases with the proximity of those activities to the streams themselves. For this assessment, we use a direct measure of riparian human disturbance that tallies eleven specific forms of human activities and disturbances (e.g., roads, landfills, pipes, buildings, mining, channel revetment, cattle, row crop agriculture, silviculture) at 22 separate locations along the stream reach, and weights them according to how close to the channel they are observed (W1_HALL in Kaufmann et al., 1999). The index generally varies from 0 (no observed disturbance) to 6 (e.g., four types of disturbance observed in the stream, throughout the reach; or six types observed on the banks, throughout the reach). Although direct human activities certainly affect riparian vegetation complexity and layering measured by the Riparian Vegetation Index, the Riparian Disturbance Index is more encompassing and differs by being a direct measure of observable human activities that are presently or potentially detrimental to streams.

Setting Expected and Altered Values for Physical Habitat Indicators

Like most chemical and biological indicators, those for physical habitat commonly vary according to their geomorphic and ecoregional setting. We defined ecoregionally specific reference conditions for Streambed Sediments, In-stream fish habitat (XFC_NAT), and Riparian Vegetative Cover (XCMGW) based on percentiles of the statistical distributions of values of these variables measured in reference sites within each ecoregion. Reference sites were screened using a set of chemistry and stressor/habitat variables that did not include the variable of interest (e.g., no sediment variables were used in screening reference sites for streambed sediments). Within any given ecoregion, streambed particle size varies considerably, so the formulation of the streambed sediment variable was used as an indicator to factor out most of the expected variability in streambed particle size associated with differences in the size and gradient of streams within each ecoregion.

Table A-5 shows the percentiles used to determine habitat indicator threshold values in the aggregated ecoregions named (e.g., 5th/25th means that we used the 5th percentile of reference sites to designate the threshold between intermediate and most-disturbed and the 25th percentile of the reference sites to designate the thresholds between intermediate and least-disturbed sites.)

Table A-5. Habitat Indicator Threshold Values

Streambed Sediments:	
10th/ 25th	CPL, NAP, NPL, SAP, SPL, TPL, XER
5th/ 25th	All other Ecoregions
In-stream Fish Habitat:	
25th/ 50th	CPL, NPL, SPL, TPL
10th/ 35th	XER
5th/ 25th	All other Ecoregions
Riparian Vegetative Cover:	
25th/ 50th	CPL, NPL, SPL, TPL
5th/ 25th	All other Ecoregions

Note that percentiles for Streambed Sediments and In-stream Fish Habitat were done separately for each of four subregions within the aggregated WMT ecoregion.

Riparian Disturbance Threshold

We did not set thresholds of alteration for this indicator based on the reference distribution. W1_HALL, the database variable name for this indicator, is a direct measure of human disturbance "pressure" – unlike the other habitat indicators, which are actually measures of habitat response to human disturbance pressures. It is very difficult to define what relatively undisturbed riparian areas are without using a screen based on these human disturbance tallies (i.e., W1_HALL). For this reason, we took a different approach for setting riparian disturbance thresholds, defining least-disturbed sites as those with W1_Hall < 0.33 and most-disturbed sites as those with W1_HALL >1.5 in all ecoregions. A value of 1.5 means that at 22 locations in the stream, the field crews found 1 of 11 types of human disturbance within the stream or right on its banks. A value of 0.33 means that one type of human disturbance was observed at one-third of the 22 riparian plots along a sample stream.

Water Chemistry Analysis

Four chemical stressors are summarized in the WSA report: total nitrogen, total phosphorus, acidity and salinity. For acidity, threshold values were determined based on values derived during the NAPAP program. Sites with acid neutralizing capacity (ANC) less than zero were considered acidic. Those with dissolved organic carbon (DOC) greater than 10 mg/L were classified as organically acidic (natural). Acidic sites with DOC less than 10 and sulfate less than 300 μeq/L were classified as acidic deposition impacted, those with sulfate above 300 were acid mine drainage impacted. Sites with ANC between 0 and 25 μeq/L were considered acidic deposition influenced, but not currently acidic.

Salinity and nutrient classes were divided into low, medium, or high classes. Salinity classes were defined by specific conductance using ecoregional specific values (Table A-6). Total nitrogen and phosphorus were classified using a method similar to that used for Macroinvertebrate Index classes using deviation from reference by aggregate ecoregion. For nutrients, the value at the 25th percentile of the reference distribution was selected for each region to define the least-disturbed condition class (low-medium boundary). The 5th percentile of the reference distribution defines the most-disturbed condition class (Table A-6). For setting nutrient class boundaries, only reference sites from the screened WSA dataset were used. Because nutrients were the focus, the two nutrient screening levels used in defining reference sites were dropped and the other seven screening factors were used by themselves to identify a set of "nutrient reference sites." Before calculating percentiles from this set of sites, outliers (values outside 1.5 times the interquartile range) were removed.

Table A-6. Nutrient and Salinity Category Criteria for WSA Assessment

Ecoregion	Salinity as Conductivity (μS/cm) Low-Medium	Salinity as Conductivity (μS/cm) Medium-High	Total N (μg/L) Low-Medium	Total N (μg/L) Medium-High	Total P (μg/L) Low-Medium	Total P (μg/L) Medium-High
CPL	500	1000	1092	2078	56.3	108
NAP	500	1000	329	441	8.2	15.7
SAP	500	1000	296	535	17.8	24.4
UMW	500	1000	716	1300	21.6	44.7
TPL	1000	2000	1750	3210	165	338
NPL	1000	2000	948	1570	91.8	183
SPL	1000	2000	698	1570	52.0	95.0
WMT	500	1000	131	229	14.0	36.0
XER	500	1000	246	462	35.5	70.0

Quality Assurance Summary

The WSA has been designed as a statistically valid report on the condition of wadeable streams at multiple scales, i.e., ecoregion (Level II), EPA region, and national, employing a randomized site selection process. The WSA is meant to complement the efforts of the EMAP Ecological Assessment of Western Streams and Rivers (EMAP West); therefore, it uses the same EMAP-documented and tested field methods for site assessment and sample collection as used by EMAP West. The WSA collected data on macroinvertebrates, water chemistry and physical habitat.

Key elements of the Quality Assurance (QA) program include:

- **Quality Assurance Project Plan** – A Quality Assurance Project Plan (QAPP) was developed and approved by a QA team consisting of staff from EPA's Office and Wetlands Oceans and Watersheds (OWOW) and Office of Environmental Information (OEI) and a Project QA Officer. All participants in the program signed an agreement to follow the QAPP standards. Compliance with the QAPP was assessed through standardized field training, site visits, and audits. The QAPP addresses all levels of the program, from collection of field data and samples and the laboratory processing of samples to standardized/centralized data management.

- **Field training and sample collection** – EPA provided 9 training sessions throughout the study area (with at least one EMAP instructor in each session) for 162 field crew members of 33 field teams. All field teams were audited on site within the first few weeks of fieldwork. Adjustments and corrections were made on the spot for any field team problems. To assure consistency, EPA supplied standard sample/data collection equipment and site container packages. 748 random site, reference site, and repeat site samples were collected.
- **Water chemistry laboratory QA procedures** – WSA used the same single lab as did EMAP West for all water chemistry samples. The Western Ecology Division (WED) was responsible for QA oversight in implementing the WSA QAPP and lab standard operating procedures (SOPs) for sample processing.
- **Benthic laboratory QA procedures** – WSA used nine benthic labs, all nine were audited for adherence to the WSA QAPP/SOP for benthic sample processing. This included internal quality control (QC) checks on sorting and identification of benthic organisms and the use of the Integrated Taxonomic Information System for correctly naming species collected, as well as the use of a standardized data management system. Independent entomologists were contracted to perform QC analysis of 10% of each labs samples (audit samples).
- **Benthic sample QC findings** – Two of the nine benthic labs satisfied the QAPP measurement objectives, while the remaining seven labs were required to implement corrective actions and are subject to a second round of QC checks. The corrective actions were due to database entry errors, incomplete QC samples, or differences in number of taxonomic groups identified to target meeting or beyond. The second round of benthic QC resulted in all but one lab meeting the measurement objectives.
- **Entry of field data** – WSA used the EMAP West data management structure, i.e., the same standard field forms for data collected in the field, with centralized data entry through scanning in to electronic data files. Internal error checks were used to confirm data sheets were filled out properly.
- **Records management** – These records include (1) planning documents, such as the QAPP, SOPs, and assistance agreements and (2) field and laboratory documents, such as data sheets, lab notebooks, and audit records. These documents are ultimately to be maintained at EPA. All data are archived in the STORET data warehouse at www.epa.gov/STORET.

For more information on the Quality Assurance procedures, refer to the EPA Web site at www.epa.gov/owow/streamsurvey/streamsurvey.

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