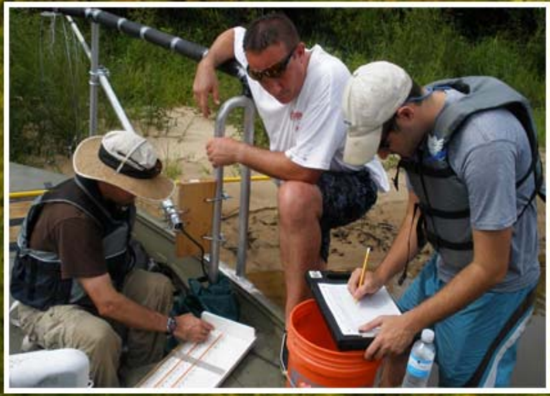
EPA

National Rivers and Streams Assessment 2008–2009

A Collaborative Survey



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http://www.epa.gov/national-aquatic-resource-surveys/nrsa

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Executive Summary

The *National Rivers and Streams Assessment 2008–2009: A Collaborative Survey* (NRSA) presents the results of an unprecedented assessment of the nation's rivers and streams. It encompasses a stunning range of waters -- from huge workhorse rivers that roll past our largest urban areas, to tiny undisturbed creeks tucked away in national parks, and everything in between. It provides information on the biological condition of the nation's rivers and streams, the key stressors that affect them, and how the condition of small streams has changed since 2004.

During the summers of 2008 and 2009, more than 85 field crews sampled 1,924 river and stream sites across the country representing nearly 1.2 million miles. Using standardized field methods, they sampled waters as large as the Mississippi River and as small as mountain headwater streams. Sites were selected using a randomized sampling technique that uses a probability-based design. This design ensures that the results of the survey reflect the variety of river and stream types and sizes across the United States. Results are presented nationally as well as by regions (three climatic and nine ecological regions).

To determine water quality conditions, sampling results were compared to conditions represented by a set of least-disturbed (or reference) sites in each of the different ecoregions. Following standard practices, the reference distribution defined ratings of good, fair and poor which were applied to the findings. This nationally consistent, regionally relevant approach for interpreting the survey data does not carry the regulatory implications of individual state water quality standards adopted under the Clean Water Act (CWA). Where available, nationally consistent indicator thresholds were used, such as the human health screening value for mercury in fish tissue.

The goals of the NRSA are to determine the extent of rivers and streams that support healthy biological condition and the extent of waters affected by a selected set of important stressors. This report does not track the origins of stressors in rivers and streams. It does provide background on the types of sources that are often associated with these stressors. In addition, the survey supports a longer-term goal: to determine whether our rivers and streams are getting cleaner and how we might best invest in protecting and restoring them.

Key findings

Biological quality

Biological condition is the most comprehensive indicator of water body health. When the biology of a stream is healthy, the chemical and physical components of the stream are typically in good condition. Twenty-eight percent of the nation's river and stream length is in good biological condition, 25% is in fair condition and 46% is in poor condition. These results are based on a robust multi-metric index (MMI) that combines several measures relevant to the condition of aquatic benthic macroinvertebrates (e.g., aquatic insects and other creatures such as crayfish). The benthic macroinvertebrates are the most common biological indicator of water quality used by states. The report presents additional biological indicators including an index of fish condition and an observed to expected ratio for macroinvertebrates. The West has 46% of river and stream length with macroinvertebrates in good condition. In the Eastern Highlands, 24% of river and stream length is in good condition. In the Plains and Lowlands, 25% is rated in good condition (See **Figure 1**). Chapter 6 presents results for 9 ecological regions.

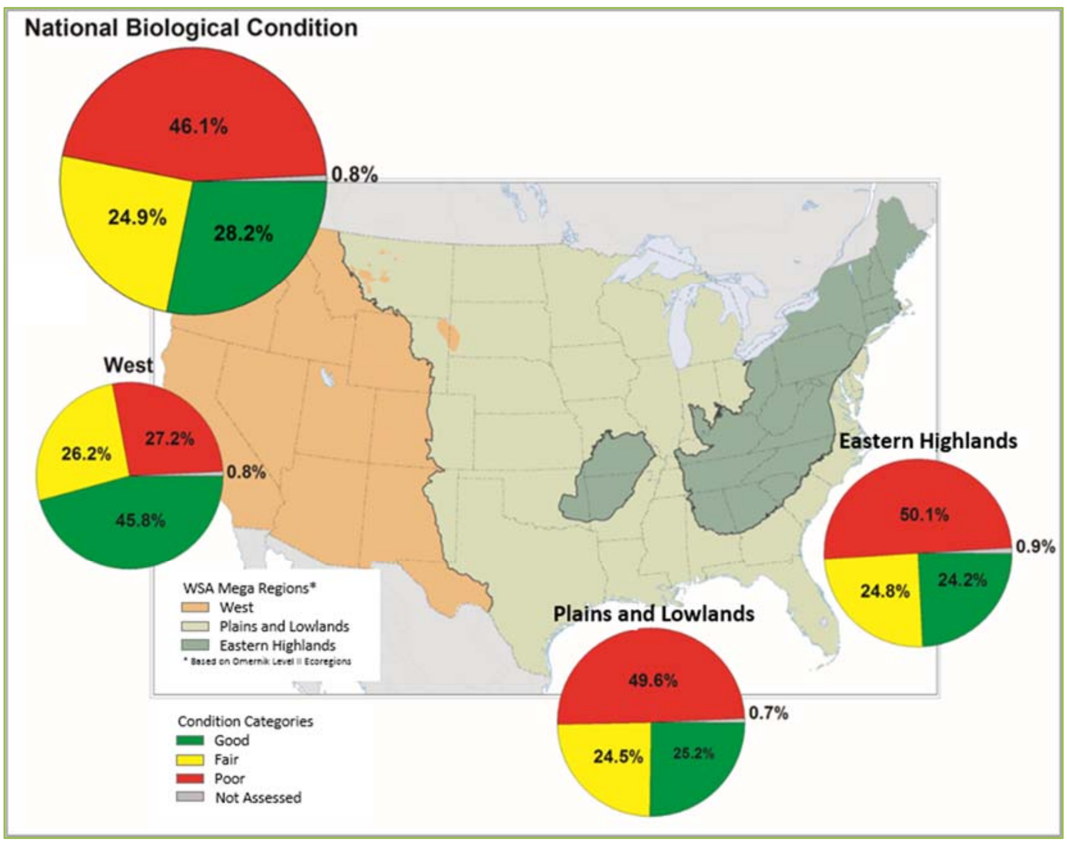


Figure 1. Biological condition of the nation's rivers and streams, based on the Macroinvertebrate Multi-metric Index (EPA/NRSA)**.**

Chemical stressors

NRSA reports on four chemical stressors: total phosphorus, total nitrogen, salinity and acidification. Of these, phosphorus and nitrogen are by far the most widespread. Forty-six percent of the nation's river and stream length has high levels of phosphorus, and 41% has high levels of nitrogen. Nutrient pollution can cause algae blooms and other problems such as low oxygen levels. Excessive levels of nutrient pollution appears to have a significant impact on biological integrity. This study documents that poor biological condition (for macroinvertebrates) is almost twice as likely in rivers and streams with high levels of phosphorus or nitrogen. Acidification, while a problem in less than 1% of U.S. river and stream length, nearly doubles the likelihood that biological condition will be poor in waters it affects.

Physical habitat stressors

Four indicators of physical habitat condition were assessed for the NRSA: streambed excess fine sediments, riparian vegetative cover (vegetation in the land corridor surrounding the river or stream), riparian disturbance (human activities near the river or stream) and in-stream fish habitat. Of these, poor riparian vegetative cover and high levels of riparian disturbance are the most widespread stressors, reported in 24% and 20% of the nation's river and stream length, respectively. These habitat conditions make rivers and streams more vulnerable to flooding, contribute to erosion and allow more pollutants to enter waterways. The NRSA finds excess streambed sedimentation in 15% of river and stream length. Sediments smother the habitat where many aquatic organisms live or breed. Poor biological condition is twice as likely in rivers and streams with excessive levels of streambed sediments.

Human health indicators

NRSA examined two indicators that provide insight into potential risks to human health: mercury in fish tissue and enterococci (bacteria). Human health screening values for mercury in fish tissue are exceeded in 13,144 miles of U.S. river length (streams were not evaluated). In 23% of river and stream length, samples exceed an enterococci threshold level for protecting human health. Waters with high levels of bacteria may be unsafe for swimming and other types of contact recreation.

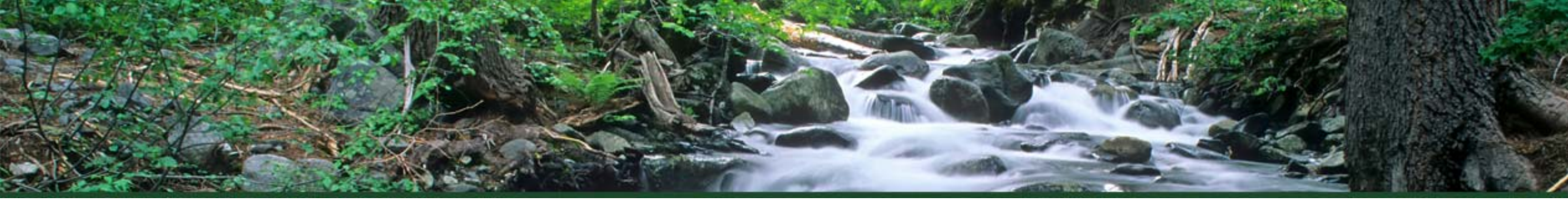
Change in stream condition

Compared to the findings of the national stream survey, WSA 2004, some statistically significant changes emerged. Nationally, the amount of stream length in good quality for macroinvertebrate condition decreased from 36.7% in 2004 to 27.8%, a decline of 8.9%. This change appears driven in large part by a 16.6% decrease in streams in good condition in the Plains and Lowlands climatic region. The percent of stream length in good condition for phosphorus dropped nationally from 50.7% to 36.4% and declined in all three major climatic regions. Several other indicators showed an increase in stream length in good condition: the percent of stream length with good riparian vegetation rose from 46.6% to 56.1%; and the percent of stream length in good condition for riparian disturbance (i.e., with low levels of disturbance) rose from 22.7% to 34.8%. These are differences *for streams only* and only occurred between two points in time. Future surveys and more data are needed to discern trends and explore the reasons for them.

Implications

A picture of the condition of the nation's rivers and streams is emerging from this survey and its predecessor streams assessment. Nearly half of our rivers and streams exhibit poor biological condition based on macroinvertebrate communities. Phosphorus, nitrogen, and streambed sediments are associated with widespread impacts on biological integrity. Analyses indicate that reducing levels of these constituents may result in measurable improvement to the biological health of rivers and streams. This survey suggests the need to address the many sources of these stressors—including runoff from urban areas, agricultural practices and wastewater—in order to ensure healthier waters for future generations.

Crew members collect macroinvertebrate samples in a wadeable stream, (Photo courtesy of Tetra Tech, Inc.)



Chapter 1. Introduction

The nation's rivers and streams

This *National Rivers and Streams Assessment 2008–2009: A Collaborative Survey* (NRSA) is the first statistically-based survey of the condition of the nation's flowing waters, from its largest major rivers to its smallest headwater streams. Unprecedented in scope, this report also compares changes in stream condition compared to an earlier study (the *Wadeable Streams Assessment* or WSA) conducted by the U.S. Environmental Protection Agency (EPA) and its partners in 2004.

Rivers and streams shape our landscape. They supply humans with drinking water, carry away our wastes and used water, irrigate our crops, power our cities with hydroelectricity and offer us myriad recreational and commercial opportunities. They support fish and other aquatic life and provide shelter, food and habitat for birds and wildlife of all types. They are the land's vast and interconnected circulatory system, carrying water, sediment and organic material from the mountains to the sea. Clean and healthy rivers and streams greatly enhance the quality of our lives.

Launching boat for sampling, (Photo courtesy of Tetra Tech, Inc.)

Over the centuries, we have radically changed most U.S. rivers and streams by interrupting their flows with dams and levees; straightening and modifying their channels for irrigation, navigation or flood control; building our cities and developing our farmland in their watersheds and floodplains; withdrawing their water for our use; and discharging our waste materials into their flow. Our rivers and streams are also subject to influences such as seasonal, annual and climate-change-induced variations in precipitation and temperature, as well as changing cycles of erosion and deposition (e.g., during flooding or dam releases). To effectively manage, restore and protect these rivers and streams, we must improve the information we have available to inform our decision making.

Some facts about large rivers

The nation's large rivers—the biggest of which are often referred to as the Great Rivers—are familiar to most of us and are part of our American history and lore. Their contribution to our nation cannot be overestimated. Some examples of their power, breadth and value are included below:

- The Mississippi River is the largest in the United States by drainage area and discharge; its watershed (i.e., the area it drains) is one of the largest in the world and covers 1.2 million square miles. At Lake Itasca, Minnesota, where the Mississippi begins, its average flow rate is 6 cubic feet per second. At New Orleans, Louisiana, the average flow rate is 600,000 cubic feet per second. Agriculture is the dominant land use in the Mississippi River basin; 60% of all grain exported from the United States is shipped on the Mississippi River to its ports at its mouth.

- The Missouri River, known as the "Big Muddy," is the longest in the United States, at approximately 2,540 miles, and drains one-sixth of the country. It begins in the Rocky Mountains in Montana, flows east and south, and joins the Mississippi River north of St. Louis, Missouri. It was the "highway" used by Lewis and Clark and became an important route for trade and westward expansion in the 1800s. The Missouri has been extensively dammed for irrigation, hydroelectricity and flood control, and its river basin is home to ten million people from 28 tribes, ten states and a small part of Canada.

- The Delaware River is the longest undammed river east of the Mississippi, flowing for 330 miles from the confluence of the east and west branches in Hancock, New York, through Pennsylvania, New Jersey and Delaware to the Atlantic Ocean. Its 13,539-square-mile watershed is only 0.4% of the land area of the conterminous United States, but it supplies water to 5% of the nation's population—over 15 million people—including residents of New York City and Philadelphia.

- The Columbia River Basin is the most hydroelectrically developed river system in the world. By volume, the Columbia is the fourth-largest river in the United States, and it has the greatest flow of any North American river draining into the Pacific. More than 400 dams, including 11 on the Columbia mainstem and hundreds of others on tributaries in the watershed, generate more than 21 million kilowatts.

- The Colorado River flows across 1,450 miles of mountainous and desert terrain from the Rocky Mountains to the Gulf of California. It supplies water to over 25 million people in seven western states, two Mexican states and 32 tribal communities; helps irrigate 3.5 million acres of farmland; and provides electricity for 30 million people. There are ten major dams on the Colorado River—including the Hoover Dam—and 80 smaller diversions, making it one of the most controlled rivers in the world.

Smaller rivers and streams

At the other end of the spectrum from the nation's large rivers are the smaller river and stream systems. These systems are often referred to as "wadeable" because they are shallow enough to sample without a boat. About 90% of perennial (i.e., continuously flowing) stream and river miles in the United States are considered wadeable. These smaller waterways are the ones we know best; they drain our neighborhoods and fields and flow past our campgrounds. They are also a critical part of the ecosystems they run through, providing food and shelter to a broad array of aquatic organisms, birds and wildlife.

Ecologists commonly define stream size according to the "Strahler stream order." The life of a river begins in its headwaters, or first-order streams; as streams of a certain order join one another, their stream order increases. Wadeable streams usually fall into the first- through fifth-order range.

Stream order affects a stream's natural characteristics, including the biological communities—the plants and animals—that live in it. For example, first- and second-order streams are often quite clear and narrow and shaded by grasses, shrubs and trees growing along their banks. The food base of these streams consists of terrestrial insects and leaves from stream-bank plants, algae that attach to rocks and wood, aquatic insects adapted to shredding leaves and scraping algae, and small fish that feed on these organisms. Healthy small streams are efficient at processing nutrients, thus reducing nutrient loads in larger downstream rivers.

Rivers that are sixth-order or higher typically appear muddy because their large flow carries accumulated sediments downstream. They are wide, so the canopy cover along their banks shades only the river's edge. The food base of wide rivers shifts away from the stream bank toward in-stream sources such as algae, small organisms that are drifting downstream, and eroded matter. The biological communities of mid-sized and large rivers are dominated by aquatic insects adapted to filtering and gathering fine organic particles, as well as by larger fish that feed on plants, animals and smaller fish.

Many streams, especially those in the arid West, do not flow year-round. These were not included in this survey because well-developed indicators to assess them are not yet available.

National Aquatic Resource Surveys

In 2004, EPA and its partners completed sampling for the first statistical survey of the condition of the nation's small, perennial streams. The survey's purpose was to establish a baseline of information on the condition of wadeable streams and the extent of major environmental stressors that affect them. Through the efforts of state environmental and natural resource agencies, federal agencies, universities and other organizations, more than 150 field biologists used standardized methods to collect environmental samples at 1,392 perennial stream locations. These sites were chosen using a statistical design to ensure that results represented the condition of *all* U.S. streams. The WSA resulted from this groundbreaking collaboration.

The WSA was initiated to address an information need identified by a number of independent organizations, including the Government Accountability Office, the National Research Council, and the National Academy of Public Administration. In the early 2000s, these organizations noted that EPA and the states did not have a uniform, consistent approach to monitoring that supported water quality decision-making. They cited EPA's approach of tallying the site-specific assessments of states did not provide a statistically representative assessment of the condition of the nation's waters. They called for more consistent and cost-effective ways to understand the magnitude and extent of water quality problems, the causes of these problems and practical ways to address them.

In response, EPA, states, tribes, academics and other federal agencies began collaborating on a series of statistically based surveys called the National Aquatic Resource Surveys (NARS) to provide the public and decision-makers with nationally consistent, statistically representative environmental information. These surveys use standardized field and laboratory protocols and follow rigorous quality assurance protocols. They are subject to peer review and meet the Agency's information quality guidelines. The NARS emerged from 15 years of EPA research and are designed to begin answering short- and long-term questions such as:

- What is the extent of waters that support a healthy biological condition, recreation and fish consumption?
- How widespread are major stressors that affect water quality?
- Are we investing wisely in water resource restoration and protection?
- Are our waters getting cleaner?

The findings of these surveys are not equivalent to the state reports on water quality described in Section 305(b) of the CWA, nor are they impaired water determinations under Section 303(d) of the CWA. Such determinations are made by the states on specific water body segments using applicable state water quality standards. Monitoring and assessment approaches used by states may vary significantly from those used in this survey and may yield different results (see “How do the NARS differ from state water quality reports under the CWA?” below).

Under the NARS program, and since the publication of the WSA in 2006, EPA, states, tribes and other partners:

- Completed a survey of the nation’s lakes, ponds and reservoirs in 2007 (the *National Lakes Assessment*, EPA 841-R-09-001) and conducted field work in the 2012 summer sampling season for the next lakes assessment;
- Completed field work, lab analyses and report development for the National Coastal Condition Assessment 2010, and conducted sampling during the summer of 2015 for the next coastal assessment;
- Completed field sampling, lab analyses and report development for the first-ever *National Wetland Condition Assessment*, and prepared for the second round of wetland assessment in 2016, and;
- Developed this NRSA report and conducted sampling in 2013-2014 for the next NRSA assessment expected to be issued in 2017.

These accomplishments would not have been possible without collaboration and partnership among field biologists and other scientists, taxonomists, statisticians, data analysts, project managers, quality control officers and reviewers in state, tribal and federal offices and universities across the country.

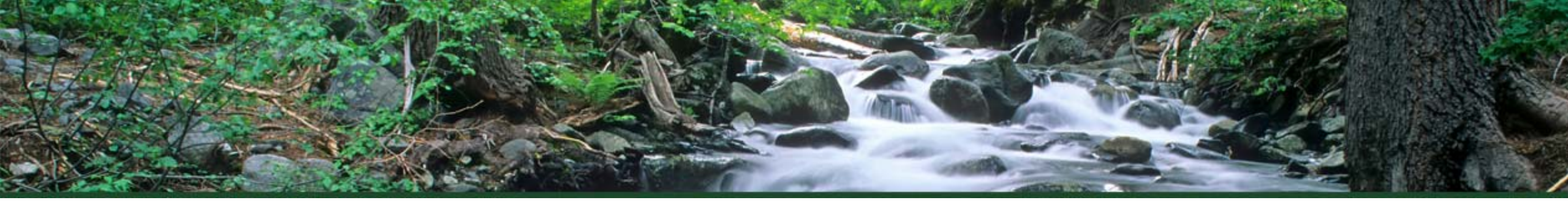
How do the NARS differ from state water quality reports under the CWA?

Under Section 305(b) of the CWA, each state prepares an assessment and reports to EPA regarding the condition of its waters, including an analysis of the extent to which its waters support the goals of the Act. Under Section 303(d), states identify waters that do not meet the applicable water quality standards and require a pollutant reduction plan, called a Total Maximum Daily Load. States use a variety of monitoring and assessment approaches to meet these requirements of the CWA and to address state-specific information needs for managing state waters. States usually collect information for a variety of parameters at targeted locations of importance to the state, such as swimming beaches, near dischargers or at drinking water sources.

State methods of collecting and assessing data vary among states and may change over time. Individual state water quality standards used to determine impairment vary from state to state. While this information is essential for states to address local water quality issues, it does not generate a nationally consistent report representative of the extent to which each state's waters support the goals of the Act for the nation as a whole or over time. State monitoring programs are not designed to answer national-level questions such as whether or not U.S. water quality is improving.

The long-term goals of the NARS include to determine conditions and trends for the nation as a whole. To do this, the surveys use a set of standardized methods to monitor for a specific set of stressors. All field crews collect the same data at each of the randomly selected representative sites across the country. Results are compared to nationally consistent or regionally relevant thresholds and reported in an overall assessment of the nation's water quality. These national surveys complement state-specific CWA reports and provide national and regional context to decision-makers.

To learn more about state CWA reporting, visit http://www.epa.gov/tmdl.



Chapter 2. Design of the National Rivers and Streams Assessment

The NRSA is the first nationally consistent survey assessing the ecological condition of the full range of flowing waters in the conterminous United States (lower 48 states). The target population includes the Great Rivers (such as the Mississippi and the Missouri), small perennial streams, and urban and non-urban rivers. Run-of-the-river ponds and pools are included, along with tidally influenced streams and rivers up to the leading edge of estuaries (head-of-salt).

The NRSA was designed to answer basic questions about the extent of rivers and streams that support healthy biological conditions and how widespread key stressors are. Over the longer term, as additional surveys in this series are completed, we will also learn whether our waters are getting cleaner over time, and whether our policy decisions to protect and restore them are effective or should be changed.

What area does the NRSA cover?

This report covers perennial rivers and streams in the conterminous United States—3,007,436 square miles. Of this area, 73% is state or private land and the rest is federal or tribal land. NRSA pilot projects in Hawaii and Alaska are also underway.

State boundaries offer few insights into the true nature of the features that affect our streams and rivers. A fundamental trait that defines our waters is annual precipitation (see **Figure 2**). On either side of the 100th meridian 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 shaped not only 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.

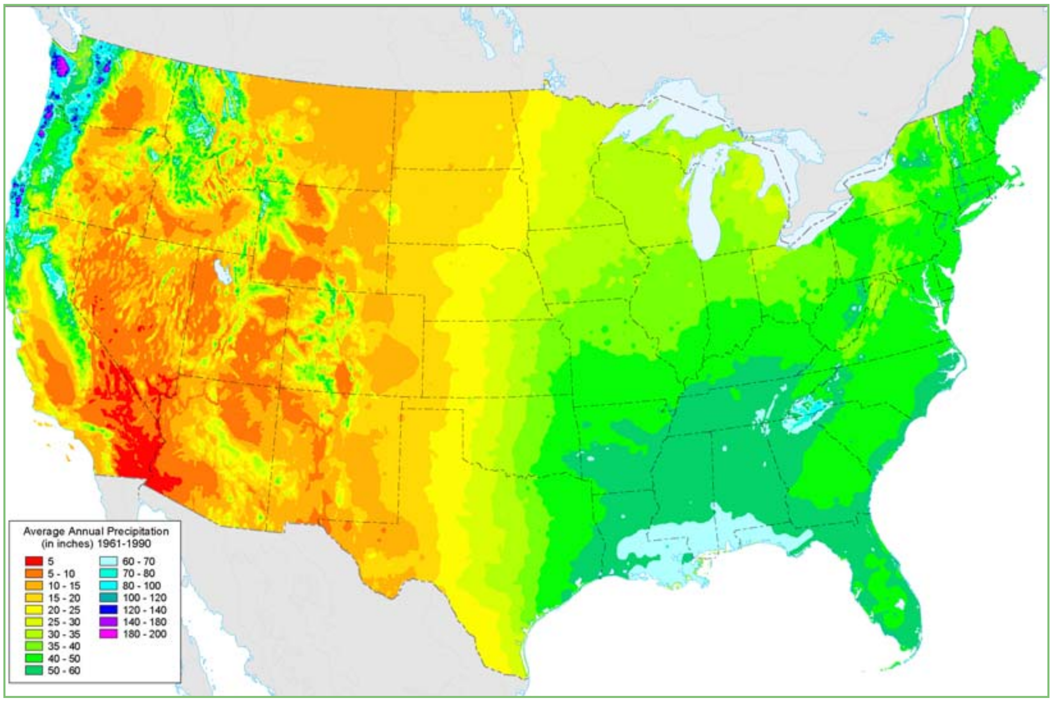


Figure 2. Average annual precipitation in the U.S. (NOAA).

This huge area includes a wide diversity of landscapes: from the maple-beech-birch forests and coastal plains of the East; to the enormous agricultural plains and grasslands of the mid-continent; to the deserts and shrub lands of the Southwest; and to the giant mountain ranges of the Rocky Mountains, Sierra Nevadas and Cascades in the west. The Appalachian Mountains, running from Maine to Alabama, cross state and climatic boundaries and separate the waters flowing to the Atlantic from those flowing to the Gulf of Mexico.

The establishment and spread of European colonies and the industrial revolution of the 18th century transformed our natural landscape as more people arrived and modified many of the features of our land and waters. Tens of thousands of dams, large and small, have altered the flow of virtually every major river and many smaller ones. The current and future condition of our waters will continue to be influenced by our population patterns and how we use all components of a watershed, including surface water, ground water and the land itself.

What regions are used to report NRSA results?

The broadest scale unit for which results are reported in the NRSA is the conterminous United States. Next are three climatic regions corresponding to major climate and landform patterns: the West, Plains and Lowlands, and

Eastern Highlands (see **Figure 3**). The body of this report describes the results for these broader-scale reporting units. The finest-scale reporting unit included in

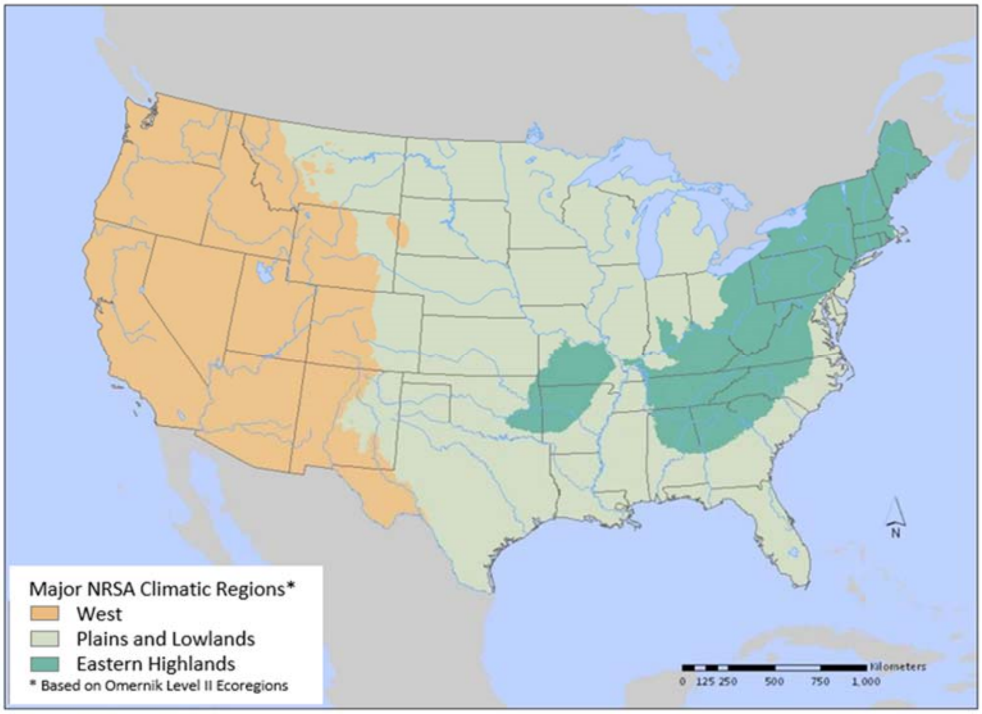


Figure 3. Major NRSA climatic regions (EPA/NRSA).

this report consists of nine ecoregions that further divide the climatic regions (see **Figure 4**). This report is not intended to focus on conditions at individual sites; its strength lies in making unbiased estimates concerning the health of the target population of U.S. rivers and streams with statistical confidence.

To get a statistically valid picture of water quality conditions within their state, some of the states participating in the NRSA increased the number of random sites they sampled within their borders to achieve finer scale, state level results. While data available for the additional sites are included in the analyses described in this report, the state-scale results are not presented. The states are preparing similar analyses that reflect their interpretation of the results in the context of state water quality standards and assessment methodologies.

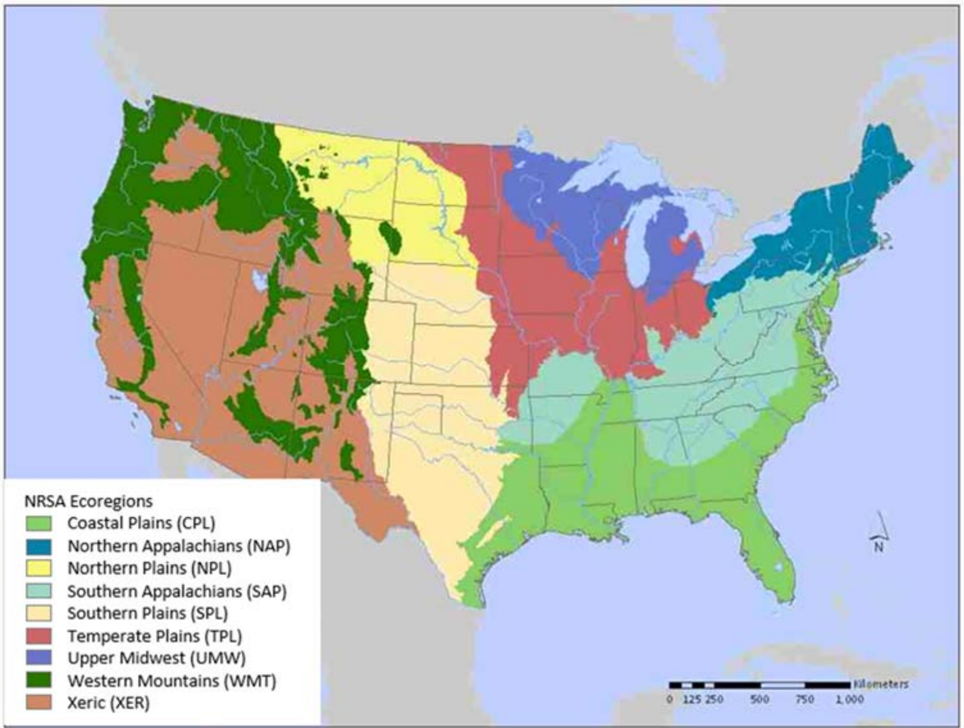


Figure 4. Nine ecoregions surveyed for the NRSA (EPA/NRSA)

The NRSA uses ecoregions to report results because the patterns of response to stress, and the stressors themselves, are often best understood in the context of these ecoregions. Typically, management practices aimed at preventing degradation or restoring water quality apply to flowing waters with similar challenges throughout an ecoregion. Both the climatic regions and ecoregions used in this report are aggregations of ecoregions as described by Omernik in 1987. Ecoregion-specific results are included in Chapter 6 of this report. The ecoregions covered in this report are described below.

- The *Eastern Highlands* climatic region is composed of the mountainous areas east of the Mississippi River. It is further divided into the Northern Appalachians ecoregion, encompassing New England, New York and northern Pennsylvania; and the Southern Appalachians ecoregion, extending from Pennsylvania into Alabama, through the eastern portion of the Ohio Valley and including the Ozark Mountains.

- The *Plains and Lowlands* climatic region includes five of the NRSA ecoregions. The Coastal Plains includes the low gradient areas of the east and southeast. It contains 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, which includes portions of Minnesota, Michigan, and Wisconsin, is dominated by lakes and has little elevation gradient. The Temperate Plains ecoregion is also known as the Corn Belt and many of its rivers drain into the Upper Mississippi River, Ohio River, and Great Lakes watersheds. The Northern and Southern Plains are better known as the Great Prairies. The Northern Plains includes the Dakotas, Montana, and northeast Wyoming. The Southern Plains encompasses Nebraska, Kansas, Colorado, Oklahoma, and Texas.

- The *Western* climatic region is defined by its Western Mountains ecoregion, which includes coastal, southwestern, and Rocky Mountain ranges, and the Xeric (i.e., arid) ecoregion that includes both the true deserts and the arid lands of portions of 11 western states and all of Nevada.

How were sampling sites chosen?

NRSA sampling locations were selected using a rigorous survey design approach. This approach, which is based on random selection, has been used in a variety of fields (e.g., health surveys, election polls and monthly labor estimates) to determine the status of populations or resources of interest using a representative sample of relatively few members or sites. This approach is especially cost-effective if the population is so numerous that all components cannot be sampled, or if it is not necessary to sample the entire resource in order to reach the desired level of precision.

In order to pick a random sample, one must first know the location of members of the population of interest. To identify the locations of perennial streams, the NRSA design team used the EPA-U.S. Geological Survey (USGS) National Hydrography Dataset Plus (NHD-Plus), a comprehensive set of digital spatial data on surface waters at the 1:100,000 scale. They also obtained information about stream order from the NHD-Plus. Table 1 shows the length of flowing waters in each of the nine ecoregions used for the NRSA.

Table 1. Length of rivers and streams represented in the NRSA, by ecoregion

Ecoregion	Miles of Rivers and Streams in NRSA
Northern Appalachians	117,742
Southern Appalachians	316,476
Coastal Plains	176,510
Upper Midwest	92,554
Temperate Plains	230,725
Southern Plains	36,570
Northern Plains	26,987
Western Mountains	151,269
Xeric	44,943

The 1,924 sites sampled for the NRSA were identified using a particular type of random sampling technique called a probability-based sample design.[1] In such a design, every element in the population has a known probability of being selected for sampling. This important feature ensures that the results of the survey reflect the full range of character and variation among flowing waters across the United States. Site selection rules included weighting to provide balance in the number of river and stream sites from each of the size classes. Site selection was also controlled for spatial distribution to make sure sample sites were distributed across the United States (see **Figure 5**). Among these randomly selected sample sites were 359 of the original 2004 WSA sites. These were revisited as part of the NRSA to enhance the analysis of whether conditions have changed. When sites were selected for sampling, research teams conducted office evaluations and field reconnaissance to determine if the sites were accessible or if a river or stream labeled as perennial in NHD-Plus was, in fact, flowing during the sampling season. If a river or stream was not flowing or was determined to be inaccessible, it was dropped from the sampling effort and replaced with a perennial river or stream from a list of replacement sites within the random design.

[1] Specifically, the NRSA uses a Generalized Random Tessellation Stratified design for selecting sites.

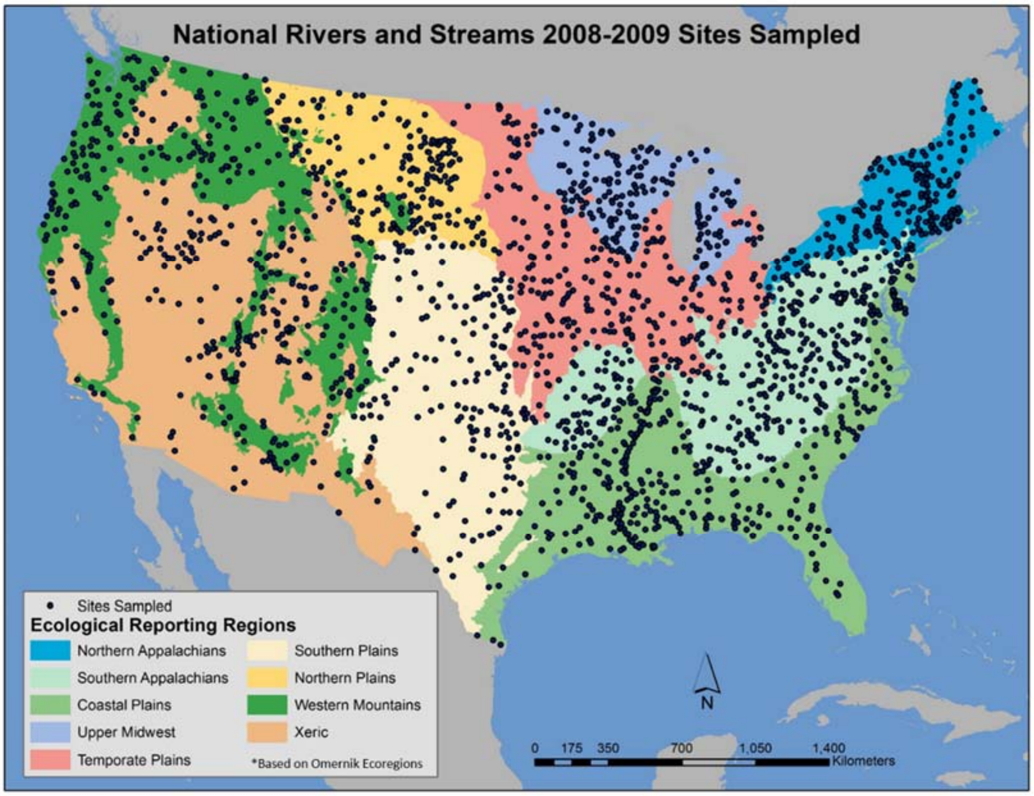


Figure 5. NRSA sample sites (EPA/NRSA).

How were waters sampled?

During the summers of 2008 and 2009, more than 85 trained crews—composed of state/tribal environmental agency, EPA and contract staff—sampled river and stream sites across the United States using standardized field protocols. The field protocols were designed to collect data relevant to the biological condition of stream resources and the key stressors affecting them. Each site was sampled by a three- or four-person field crew, usually under base (normal) flow conditions.

During each site visit, crews laid out the sample reach (i.e., stretch of river or stream) and transects to guide data collection (see **Figure 6**). Field crews collected water samples that were sent to a lab for basic chemical analysis; they also collected biological samples from 11 transects (fixed paths along each stream reach) that were sent to taxonomists for identification. Crews recorded extensive data on field forms and documented 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 across all 48 states included in the NRSA is a key feature of the survey. It allows the data to be combined to produce a nationally consistent assessment. This standardization is necessary: states, tribes, academics, and federal agencies typically use a wide range of methods to sample streams and rivers for their own programs, and inconsistent results might have arisen from them had different methods been used in this survey. Crews collected physical, chemical and biological data at all NRSA sites. Pilot projects using these standardized method were also conducted in Alaska and Hawaii.

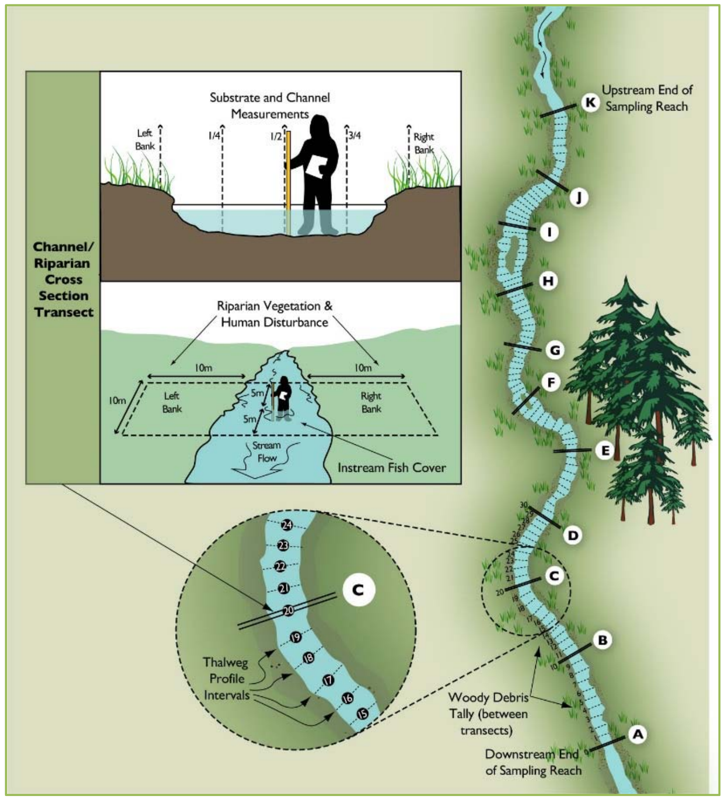
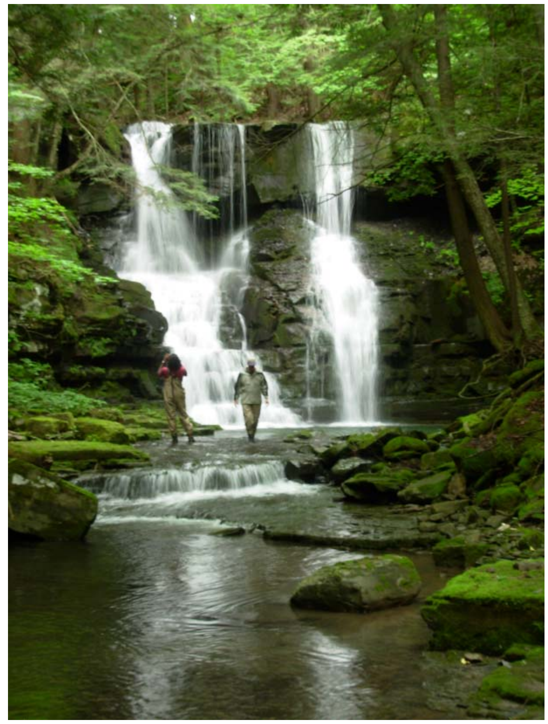


Figure 6. Reach layout used for sampling in the NRSA (EPA/NRSA).

What data were collected?

The NRSA uses benthic macroinvertebrates (e.g., insects and other small animals such as snails and crayfish) and fish as biological indicators of condition. It focuses on these groups of organisms because they are each sensitive to different disturbances that result from human activities and therefore give us a measurement of the *biological integrity* of rivers and streams. Additionally, crews collected algae for analysis. Information on this research biological indicator is presented in Chapter 7.

Biological integrity has been defined as "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" (Karr and Dudley, 1981). Macroinvertebrates are included in almost every state and federal program monitoring rivers and streams, and they are increasingly evaluated by volunteer water quality monitoring organizations. Water quality monitoring and management programs are also enhancing their understanding of biological integrity by adding other biological assemblages, including fish and algae.



Sampling near a waterfall. (Photo courtesy of Tetra Tech, Inc.)

The NRSA supplements information on the biological condition of rivers and streams with measurements of key stressors that might negatively influence or affect river and stream condition. Stressors are the chemical, physical and biological components of the ecosystem that have the potential to degrade biological integrity. While some result exclusively from natural or human sources, most stressors come from a combination of both. The challenge is in understanding and effectively minimizing the pressures humans exert on aquatic systems through their use of the surrounding environment.

Examples of *chemical stressors* are excess nutrients (nitrogen and phosphorus), salinity, and acidification. Most *physical stressors*—such as excess sedimentation, bank erosion and loss of streamside trees and vegetation—are created when the physical habitat within the watershed of a stream network is altered. One of the key components of an ecological assessment is a measure of how common each stressor is in a region, and how severely it affects biological integrity.

In addition to these stressors, the NRSA investigated *human health indicators,* specifically mercury levels in fish tissue and the fecal indicator enterococci.

Table 2 shows the key indicators evaluated for this report. NRSA scientists sampled for a number of other indicators as well; future reports may discuss these, but they are not included here due to technical and time considerations.

Table 2. Indicators evaluated for the NRSA

Biological Indicators	Chemical Indicators	Physical Indicators	Human Health Indicators
• Benthic macroinvertebrates • Algae (research) • Fish community	• Phosphorus • Nitrogen • Salinity • Acidity	• Streambed sediments • In-stream fish habitat • Riparian vegetative cover • Riparian disturbance	• Enterococci (fecal indicator) • Mercury in fish tissue

Setting expectations

Choosing reference streams and rivers

To interpret the data collected by the NRSA field crews and assess current ecological condition, results were compared to conditions in a set of reference rivers and streams. For the NRSA, this set of reference sites represents "least-disturbed condition," or the best physical habitat and chemical and biological conditions available given today's state of the landscape.

To identify sites that would qualify as "least disturbed" or reference, EPA evaluated hand-selected sites from rivers and streams considered by state and federal experts to be of high quality, as well as sites from the randomly selected target populations. Field crews sampled the hand-selected sites using the same protocols they used in sampling sites in the target population. For some indicators, data from the previous WSA were also used. Analysts compared data results from all of the sampled river and stream sites against screening criteria to determine the final set of sites that would characterize the reference condition. NRSA analysts used a number of independent variables, such as total nitrogen and turbidity, as screening criteria. The criteria for the screening variables varied from region to region to reflect the natural variability across the U.S. landscape. The screening criteria were developed with the goal of identifying the least amount of human disturbance in each ecoregion.

Among reference sites, there are two sources of variability:

- Natural variability—the wide range of habitat types naturally found within each ecoregion—creates a spread of reference sites representing those different habitats. Capturing natural variability in reference sites helps establish reference conditions that represent the range of natural environments in the ecoregions.

- Human activities have changed many areas in the United States, with natural landscapes transformed by urban and suburban development, agricultural activities and resource extraction. The extent of these disturbances varies across regions. Some regions have reference sites in watersheds with little to no evidence of human impact. Other regions have few sites that have not been influenced by human activities. A challenge in applying least disturbed reference approach is accounting for regional differences in the quality of available least-disturbed sites. The NRSA analysts endeavor to address this through statistical tools described in the technical report.

Setting the thresholds for good, fair and poor

Two types of assessment thresholds or benchmarks—fixed and distribution-based—were used in the NRSA to establish good, fair and poor condition for each of the indicators. Fixed thresholds are based on accepted values from peer-reviewed, scientific literature and are typically well established and/or widely and consistently used by water quality agencies. An example of this is the human health screening value of 300 parts per billion for mercury in fish tissue. The second type of threshold is based on the distribution of values of a particular indicator derived from data from reference sites.

The range of conditions found in reference sites for an ecoregion describes a distribution of values expected for least-disturbed condition. For an indicator, thresholds were chosen using defined percentiles from the range of values (the distribution) in all of the reference sites in a region. Following established approaches, the NRSA uses percentiles of the reference distribution to determine thresholds. Sites rate good when indicator scores are as good as the best 75% of the reference distribution. Sites rate poor when they score worse than the worst 5% of the reference distribution. Fair sites fall in between. No single score from an individual reference site is used to establish a threshold; the thresholds are a percentile from the reference distribution. Because expectations vary naturally across ecoregions, the final thresholds reflect the least-disturbed conditions established for each ecoregion.

Figure 7 is an illustrative graph of the percentiles drawn from the reference distribution curve on the right and applied to the full population curve on the left. For biological indicators the NRSA applied the 5^{th} percentile of the reference distribution to separate the most-disturbed sites (poor) from moderately disturbed sites (fair). This means that river and stream miles in the most-disturbed category are worse than 95% of the sites used to define reference condition. Similarly, the 25th percentile of the reference distribution was used to distinguish between moderately disturbed sites (fair) and least-disturbed sites (good); river and stream miles reported as least-disturbed are as good as 75% of the sites used to define reference condition. These good, fair and poor condition classes have no regulatory implications; they are not replacements for the evaluation by states and tribes of the quality of rivers and streams relative to

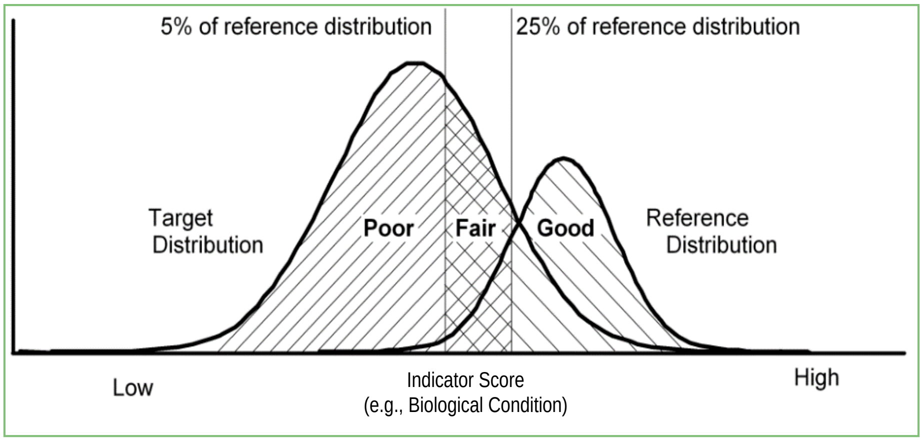


Figure 7. Reference condition thresholds used for good, fair and poor assessment (EPA/NRSA).

water quality standards.

NRSA partners supported this reference-condition-based approach, which is consistent with EPA guidance and state practice. Interested readers can find more detailed information about determining reference condition in the "Sources and References" section of this report and in the NRSA technical report, published online at http://www.epa.gov/national-aquatic-resource-surveys/nrsa.

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Understanding biological condition

The objective of the CWA is to restore and maintain the chemical, physical and biological integrity of the nation's waters. It establishes many national goals to control pollution, including that water quality support healthy aquatic communities and provide for recreational uses like swimming and fishing wherever attainable. A primary goal of the NRSA is to develop a baseline understanding of the biological condition of our nation's rivers and streams.

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 water bodies. Aquatic plants and animals are constantly exposed to various stressors. Therefore, they reflect not only current conditions, but also the cumulative impacts of stressors and changes in conditions over time.

Benthic macroinvertebrates (aquatic insects, crustaceans, worms and mollusks that live in river and stream beds and in vegetation) are widely used by states, tribes, federal agencies and watershed organizations to determine biological condition. These organisms can be found in all rivers and 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—that is, pollution-tolerant species will survive in degraded conditions, and pollution-intolerant species will die. These communities are also critically important to fish because most game and non-game species require a good supply of benthic macroinvertebrates as food. Biologists have been studying the health and composition of benthic macroinvertebrate communities in streams for decades. Biological condition is the most comprehensive indicator of water body health; when the biology of a stream is healthy, the chemical and physical components of the stream are also typically in good condition. In fact, several states have found that biological data frequently detect stream impairment where chemistry data do not.

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

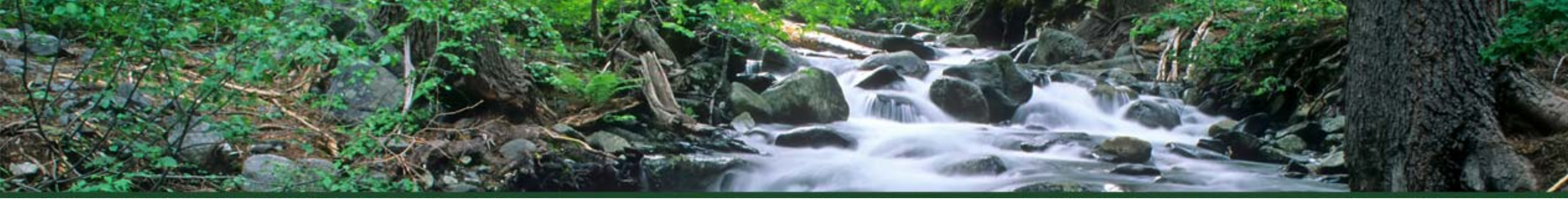
Using multiple biological assemblages to determine biological condition

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

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

The NRSA uses benthic macroinvertebrates and fish as biological indicators of ecological condition. This is the first time these two biological assemblages have been evaluated for one national, statistically representative survey. For each of these assemblages, scientists calculated a series of metrics or individual measures and combined them into index scores. Results for each of these assemblages are presented in this report. The NRSA also collected and analyzed data on algae. Information related to this research indicator is presented in Chapter 7. USGS recently released a report using these three indicators at hand-selected sites across the United States, further highlighting their value.

Research is still underway to determine how the different assemblage indices can be accurately combined into one overall index. Therefore, the macroinvertebrate assemblage indicator—and specifically the macroinvertebrate multi-metric index (MMI)—was selected to represent overall biological condition for the purposes of this report. The MMI integrates a broad variety of informative macroinvertebrate metrics into one overall result and provides a particularly strong picture of biological condition that is widely used by state water quality agencies to assess and report on their rivers and streams. It was also used as the primary indicator of biological condition in the 2004 WSA. Work is ongoing to explore methods for integrating different assemblage indices into one overall index for future reports in this series.



Chapter 3. Condition of the Nation's Rivers and Streams

Background

The goal of the CWA is "to restore and maintain the *chemical*, *physical*, and *biological* integrity of the Nation's waters." The NRSA examines these three aspects of water quality through a set of commonly used and widely accepted indicators. It does not include all aspects of aquatic ecosystem integrity or review all possible chemical, physical or biological stressors known to affect water quality.

This chapter discusses the core indicators of biological condition that were measured and analyzed for the NRSA, the chemical and physical aquatic indicators of stress, and a ranking of the relative importance of the stressors in affecting biological condition. Results for each indicator are shown for the nation's rivers and streams and for the three major climatic regions (Eastern Highlands, Plains and Lowlands, and West). Chapter 4 presents the findings of the human health indicators, and Chapter 6 presents indicator results for each of the nine NRSA ecoregions. An analysis of the changes between this study and the 2004 WSA is presented in Chapter 5. It is important to keep in mind that the overall NRSA findings should not be compared directly to those of the WSA because of the difference in overall population surveyed (rivers and streams versus streams only).

Indicators of biological condition

Ecologists evaluate the biological condition of rivers and streams by analyzing key characteristics of the communities of organisms that live in them. These characteristics include the composition and relative abundance of related groups of organisms that represent a portion of the overall biological community. The NRSA focuses on two such key groups, known as *assemblages*: benthic macroinvertebrates (aquatic insects, crustacean, worms and mollusks that live at the bottom of rivers and streams) and fish. Information on another biological indicator still in its research phase, algae, is presented in Chapter 7. This is the first time two different biological assemblages were evaluated for one national statistical survey. Scientists evaluated both groups to secure as robust an understanding of the biological condition of rivers and streams as practical. Each assemblage plays a different role in the way that rivers and streams function. For example, macroinvertebrates feed on algae and other organic material and are also an important food source for many other aquatic animals, such as fish; in turn, fish serve as an important food source for people and wildlife. Each of these groups of aquatic organisms is sensitive in its own way to human disturbances.

NRSA researchers collected samples of these organisms and sent them to laboratories for analysis, yielding datasets that provided the types and number of taxa (i.e., classifications or groupings of organisms) found at each site. These datasets were then analyzed to assess the condition of each group of organisms, using well-established and tested indices. As a final step in interpreting this information, analysts developed a ranking system for the stressors that affect each of these biological assemblages.

Macroinvertebrate Multi-metric Index

Macroinvertebrates are widely used as indicators of biological condition because they respond to human disturbance in known and predictable ways. Given their broad geographic distribution, abundance, ease of collection and connection to fish and other aquatic animals (i.e., as a source of food), these organisms serve as excellent indicators of the biological quality of rivers and streams and of the human stressors that affect them.

Collecting macroinvertebrates from a stream, (Photo courtesy of Eric Vance, EPA.)

The macroinvertebrate multi-metric index (MMI) is a total index score that is the sum of scores for a variety of individual measures (also known as metrics). To determine the macroinvertebrate MMI, ecologists selected six metrics indicative of different aspects of macroinvertebrate community structure:

- Taxonomic richness — the number of distinct families or genera within different taxonomic groups of organisms, within a sample. A sample with many different families or genera, particularly within those groups that are sensitive to pollution, indicates least-disturbed physical habitat and water quality and an environment that is not stressed.

- Taxonomic composition — the proportional abundance of certain taxonomic groups within a sample. Certain taxonomic groups are indicative of either highly disturbed or least-disturbed conditions, so their proportions within a sample serve as good indicators of condition.

- Taxonomic diversity — the distribution of the number of taxa and the number of organisms among all the taxonomic groups. Healthy rivers and streams have many organisms from many different taxa; unhealthy streams are often dominated by a high abundance of organisms in a small number of taxa.

- Feeding groups — the distribution of macroinvertebrates by the strategies they use to capture and process food from their aquatic environment (e.g., filtering, scraping, grazing or predation). As a river or stream degrades from its natural condition, the distribution of animals among the different feeding groups will change, reflecting changes in available food sources.

- Habits/habitats — the distribution of macroinvertebrates by how they move and where they live. A stream with a diversity of habitat types will support animals with diverse habits, such as burrowing under streambed sediments, clinging to rocks, swimming and crawling. Unhealthy systems, such as those laden with silt, will have fewer habitat types and macroinvertebrate taxa with less diverse habits (e.g., will be dominated by burrowers).

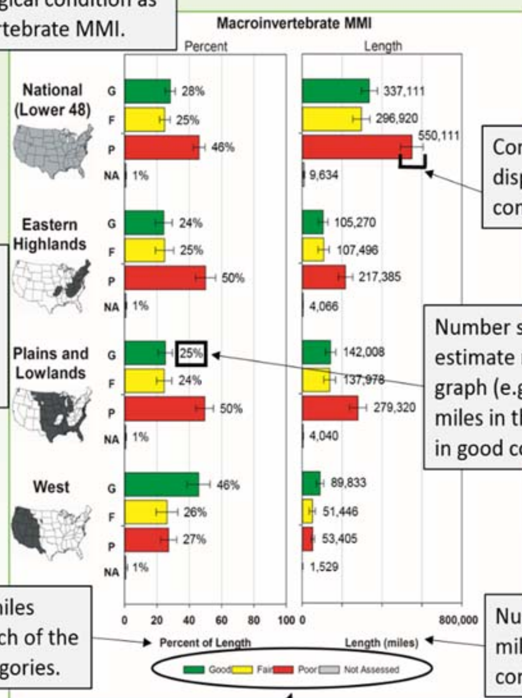
- Pollution tolerance — the distribution of macroinvertebrates by the specific range of contamination they can tolerate. Highly sensitive taxa, or those with a low tolerance to pollution, are found only in rivers and streams with good water quality. Waters with poor quality will support more pollution-tolerant species.

The specific metrics chosen for each of these characteristics varied among the nine ecoregions used in the analysis.

Because it integrates a broad variety of informative macroinvertebrate metrics into one overall result, the macroinvertebrate MMI provides a particularly strong picture of biological condition that is widely used by state water quality agencies to assess and report on their rivers and streams. It was also used as the primary indicator of biological condition in the 2004 WSA. For these reasons, and because it is not yet possible to integrate the indices for different biological assemblages into one overall result, the macroinvertebrate MMI serves as the key indicator of biological condition for the NRSA as well. Work is ongoing to explore methods for integrating different assemblage indices into one overall index for future reports in this series.

How to Read and Interpret NRSA Results Figures

This example figure displays national and ecoregion estimates of biological condition as measured by the Macroinvertebrate MMI.



National estimates of condition are shown by the first group of bars, followed by estimates for the three climatic regions.

Confidence interval – displays level of certainty or confidence in the estimate.

Number shows the value of the estimate represented by the bar graph (e.g., 25% of river/stream miles in the Plains and Lowlands is in good condition).

Proportion of river/stream miles nationally or regionally in each of the condition or stress level categories.

Number of river/stream miles in each of the condition categories.

Condition classes are indicated by colors
Green – good condition or low stress
Yellow – Fair condition or moderate stress
Red – poor condition or high stress
Grey – unassessed or no data

Findings for the Macroinvertebrate Multi-metric Index

As illustrated in **Figure 8**, the macroinvertebrate MMI results show that 28% of the nation's river and stream length (337,111 miles) is in good condition, 25% (296,920 miles) is in fair condition, and 46% (550,111 miles) is in poor condition compared to least-disturbed reference conditions. Of the three major climatic regions, the Eastern Highlands and the Plains and Lowlands have the highest percentage of river and stream length in poor condition (50% or 217,385 miles; and 50% or 279,320 miles, respectively), followed by the West (27%, or 53,405 miles).

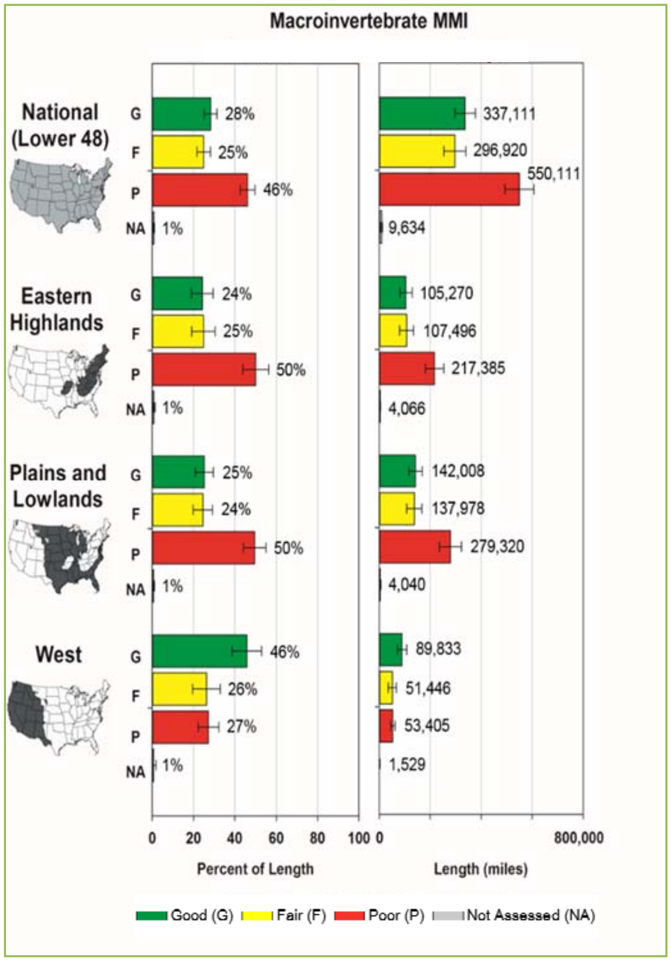


Figure 8. Biological condition of the nation's rivers and streams based on the macroinvertebrate MMI (EPA/NRSA.) This index combines metrics of benthic community structure and function into a single index for each region.

Macroinvertebrate Observed/Expected Ratio of Taxa Loss

The macroinvertebrate observed/expected ratio of taxa loss (or O/E taxa loss) measures taxa that have been lost at a site. The taxa expected at individual sites (E) are predicted from a model developed from data collected at least-disturbed sites. By comparing the list of taxa observed (O) at a site with those expected to occur, the proportion of expected taxa that have been lost can be quantified as the ratio of O/E. O/E taxa loss models are calibrated for the specific natural conditions in each area for which they are used. For the NRSA, analysts developed three O/E taxa loss models to predict the extent of taxa loss in rivers and streams in the Eastern Highlands, Plains and Lowlands, and West.

O/E taxa loss values range from 0 (none of the expected taxa are present) to slightly greater than 1 (more taxa are present than expected). Each tenth of a point less than 1 represents a 10% loss of taxa at a site, so a score of 0.9 indicates that 90% of the expected taxa are present and 10% are missing. The quality of reference sites available for a region sets the bar for what is expected, so regions with lower-quality reference sites will have a lower bar. It is important to keep in mind that this indicator examines only one specific aspect of biological condition (biodiversity loss), while the macroinvertebrate MMI discussed above combines multiple characteristics. Therefore, results are not expected to be the same.

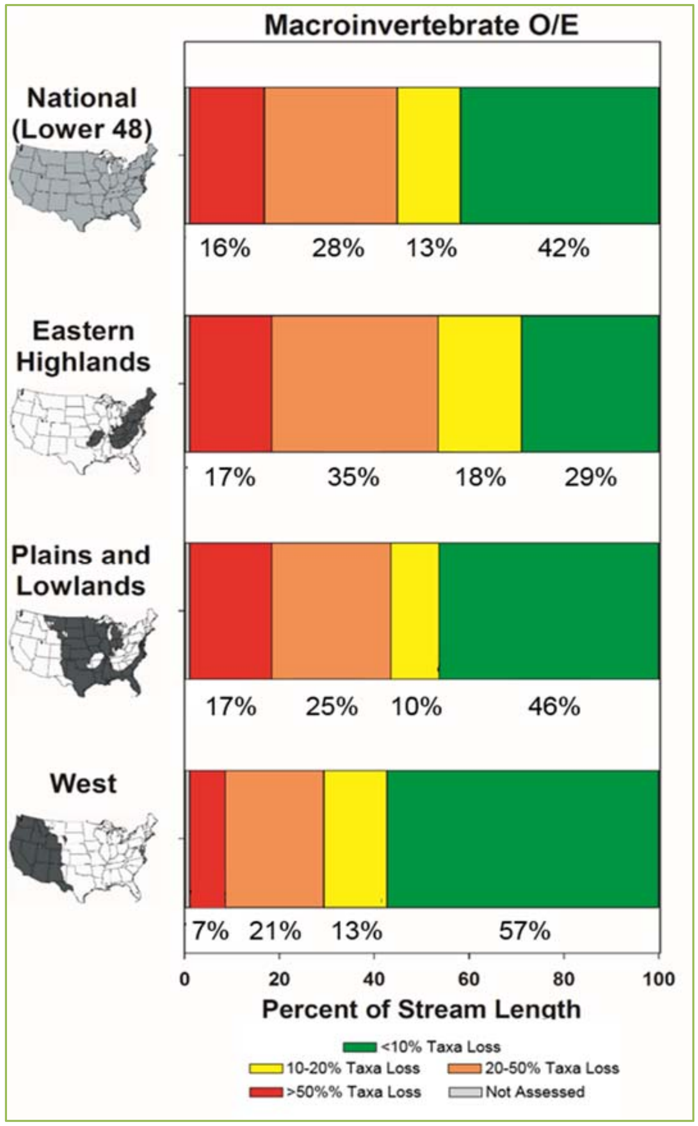


Figure 9. Macroinvertebrate taxa loss in the nation's rivers and streams as measured by the O/E taxa loss (EPA/NRSA). This indicator displays the loss of taxa compared to the reference sites for each region. Unassessed area accounts for 1% nationally and for each region.

Findings for O/E Taxa Loss

Findings for O/E taxa loss are presented in four categories: (1) less than 10% taxa loss, (2) 10%–20% taxa loss, (3) 20%–50% taxa loss, and (4) more than 50% taxa loss. As shown in **Figure 9**, 42% of U.S. river and stream length has lost less than 10% of taxa; 13% lost 10%–20% of taxa; 28% lost 20%–50% of taxa; and 16% lost more than 50% of expected taxa.

Of the three major regions, the West has the highest percentage of river and stream length with 10% or less taxa loss (57%) and the smallest percentage with more than 50% taxa loss (7%). The Plains and Lowlands and the Eastern Highlands each have 17% of river and stream length with more than 50% taxa loss; however, the Plains and Lowlands has a greater percentage of stream length in the good range with less than 10% taxa loss (46% versus 29% for the Eastern Highlands).

Fish Multi-metric Index

Evaluating the variety and abundance of fish species (the fish assemblage) in rivers and streams has been an important component of many water monitoring and water quality management programs. Fish are sensitive indicators of physical and chemical habitat degradation, environmental contamination, migration barriers and overall ecosystem productivity. They need plants, insects and benthic macroinvertebrates to eat; in-stream and streambank cover for shelter; appropriate streambed substrate conditions for spawning; and overhanging vegetation to shade the water in which they live. They are affected by changes in temperature, dissolved oxygen, pH and myriad other physical and chemical constituents in water. They are also long-lived, will move (if they can) to avoid pollutants or other stresses, and are economically, culturally and recreationally valuable. Determining the health of the fish assemblage helps evaluate the extent to which our waters are meeting the goals of the CWA.

For the NRSA, scientists developed a fish MMI to assess condition of the fish community at individual sites. Separate indices have been developed for each of the three major climatic regions. These indices are based on a variety of metrics, including taxonomic richness, taxonomic composition, pollution tolerance, habitat and feeding groups, spawning habits (specifically, the percent of individuals that deposit eggs on or within the substrate in shallow waters), the number and percent of taxa that are migratory and the percent of taxa that are native. Fish are collected using standard electrofishing methods, tallied and identified in the field. Except for those used for tissue analysis and as voucher specimens, they are then released alive.

Fish collection, (Photo courtesy of Marsha Landis.)

Findings for the Fish Multi-metric Index

As shown in **Figure 10**, the NRSA fish MMI indicates that 36% of the nation's river and stream length (427,992 miles) is in good condition for this indicator, 19% (232,147 miles) is in fair condition, and 32% (384,055 miles) is in poor condition compared to least-disturbed conditions. The remaining 13% of river and stream length either is not assessed or, for various reasons, has insufficient data. The percentage unassessed is relatively large because some federal, state and local authorities denied fish collection permits (often because of the possible presence of threatened or endangered species) and because some conditions and sites were deemed unsafe or unsuitable for fish sampling.

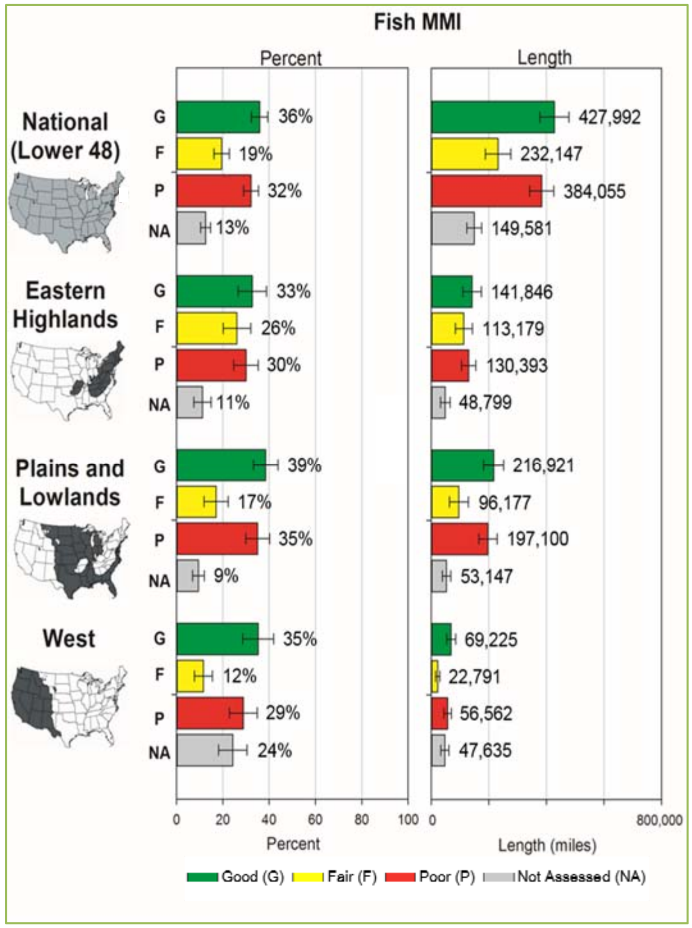


Figure 10. Condition of the fish assemblage in the nation's rivers and streams as measured by the fish MMI (EPA/NRSA). This index combines metrics of fish assemblage structure and function into a single index for each region.

Of all regions, the Plains and Lowlands region has the highest percentage of stream length in poor condition at 35% (197,100 miles), with 39% (216,921 miles) in good condition. For the Eastern Highlands, 30% of river and stream length (130,393 miles) ranks in poor condition, and 33% (141,846 miles) ranks in good condition. In the West, 29% (56,562 miles) of river and stream length is in poor condition, and 35% (69,225 miles) is in good condition. The West has the largest percentage of stream length that is either unassessed or has insufficient data. Care should be taken in interpreting these results and when comparing them with other regions.

Aquatic indicators of stress

In the aquatic environment, a stressor is anything that could adversely affect the community of organisms residing there. For the NRSA, specific chemical and physical stressor indicators were selected for sampling because the stressors are widespread, are of potential concern and can be cost-effectively measured. These indicators of stress were not intended to be all-inclusive. Some important stressors were not included in the survey due to technical or cost constraints. Several others were sampled—primarily more cutting-edge indicators or more complex analytes—but are still undergoing analysis and are not included in this report. EPA and its partners will be reporting on these stressors in supplemental technical documents or peer-reviewed journals.

NRSA indicators are based on direct measures of stress in the river or stream or in its adjacent riparian areas. In this report, we do not track the sources of these stressors, which can come from a wide variety of human activities, natural sources and land uses. This report does provide background on the types of sources that are associated with these stressors and suggests that, in general, tackling such sources will help in reducing problems nationwide. To address a specific river or stream, the sources pertinent to that site and for that watershed need to be identified.

Figures 11 through 18 summarize the national and regional results for chemical and physical stressors. See the "Ranking Stressors" section below for a discussion of the severity of impacts from individual stressors and the benefits that would be derived if those stressors were reduced or eliminated. The purpose of these NRSA analyses is to help rank the different threats posed by stressors to our water resources and assist in setting priorities for management actions.

Chemical stressors

Four chemical stressors were assessed as indicators in the NRSA: total phosphorus, total nitrogen, salinity and acidification. These stressors were selected because of national or regional interest about the extent to which they might be affecting the quality of the biological communities in rivers and streams, and to allow a comparison of findings with the 2004 WSA. Scientists developed thresholds for interpreting the data for these indicators from a set of least-disturbed reference sites for each of the nine NRSA ecoregions, as described in Chapter 2.

Nutrients and eutrophication in rivers and streams

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

Nutrient enrichment due to human activities has long been recognized as one of the leading pollution challenges facing our lakes, reservoirs and estuaries. It has also been more recently recognized as a contributing factor to river and stream degradation. Nutrient over-enrichment of rivers and streams is a problem because of the negative impacts on aquatic life, adverse health effects on humans and domestic animals, aesthetic and recreational use impairment and excessive nutrient input into downstream water bodies.

Excess nutrients can lead to excessive growth of phytoplankton (free-floating algae) in slow-moving rivers; periphyton (algae attached to the substrate) in shallow streams; and macrophytes (aquatic plants large enough to be visible to the naked eye) in all waters. Unsightly filamentous algae can impair the aesthetic enjoyment of rivers and 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 water intake screens.

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

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

Total phosphorus

Phosphorus is an essential nutrient in the environment and a common component of fertilizers. Because of the naturally low concentrations of phosphorus in most rivers and streams, even small increases can adversely affect water quality and biological condition. High concentrations in rivers and streams may be associated with agricultural practices, runoff from urban areas and lawns, leaking septic systems or discharges from sewage treatment plants. Too much phosphorus can lead to increased growth of algae and large aquatic plants; decaying algae and plants reduce dissolved oxygen levels and water clarity, interfere with swimming and reduce aesthetic enjoyment of our waters.

High levels of phosphorus can also lead to algae blooms that can produce toxins harmful to human and animal health. Natural variability in phosphorus concentrations is reflected in the regional thresholds for good, fair and poor conditions (i.e., low, medium and high levels), which are based on least-disturbed reference sites for each of the nine NRSA ecoregions.

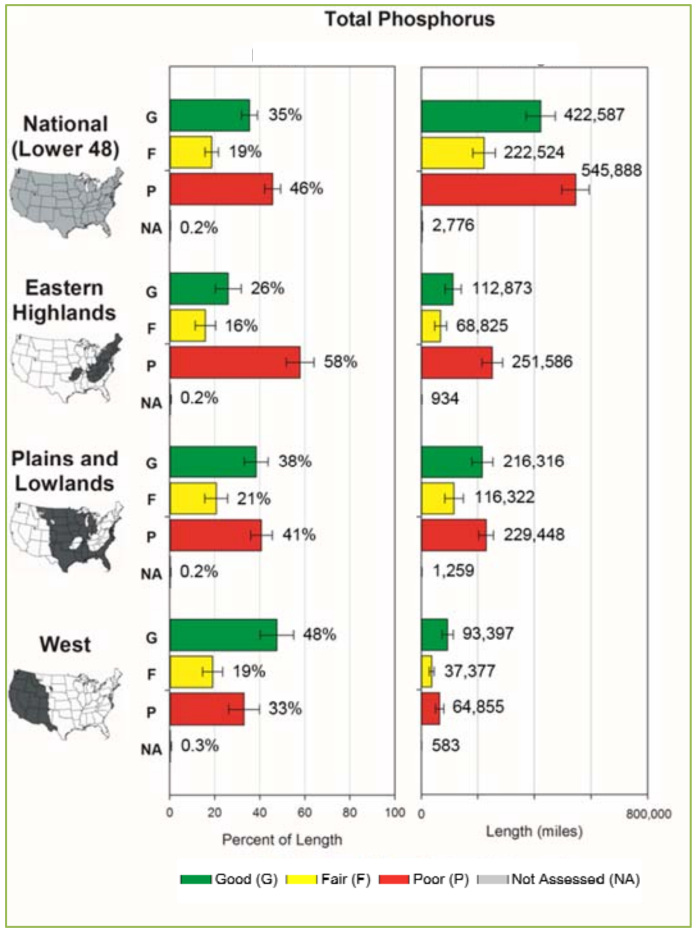


Figure 11. Total phosphorus concentrations in the nation's rivers and streams (EPA/NRSA). Percentages of river and stream length in good, fair and poor condition are based on phosphorus concentrations compared to least-disturbed regional reference sites.

Findings for total phosphorus

Compared to least-disturbed reference conditions, approximately 35% (422,587 miles) of the nation's river and stream miles are in good condition for phosphorus, 19% (222,524 miles) are in fair condition, and 46% (545,888 miles) are in poor condition (**Figure 11**). Of the three major climatic regions, the Eastern Highlands region has the greatest proportion of river and stream length in poor condition based on phosphorus levels (58%, or 251,586 miles).

Total nitrogen

Nitrogen is an essential nutrient that, at high concentrations, can stimulate excess growth of algae and large aquatic plants. Common sources associated with excess nitrogen include fertilizers, wastewater, animal wastes and atmospheric deposition. Low dissolved oxygen levels, algae blooms and degraded habitat conditions for benthic macroinvertebrates and other aquatic life can result from high nitrogen concentrations.

Findings for total nitrogen

About 38% (458,040 miles) of the nation's river and stream miles are in good condition for nitrogen compared to least-disturbed reference conditions (**Figure 12**). About 20% (238,445 miles) are rated fair for nitrogen, and 41% (494,514 miles) are rated poor. The Plains and Lowlands show the greatest proportion of river and stream length in poor condition for high concentrations of nitrogen (47%, or 267,170 miles), followed by the Eastern Highlands (43%, or 188,613 miles) and the West (20%, or 38,731 miles).

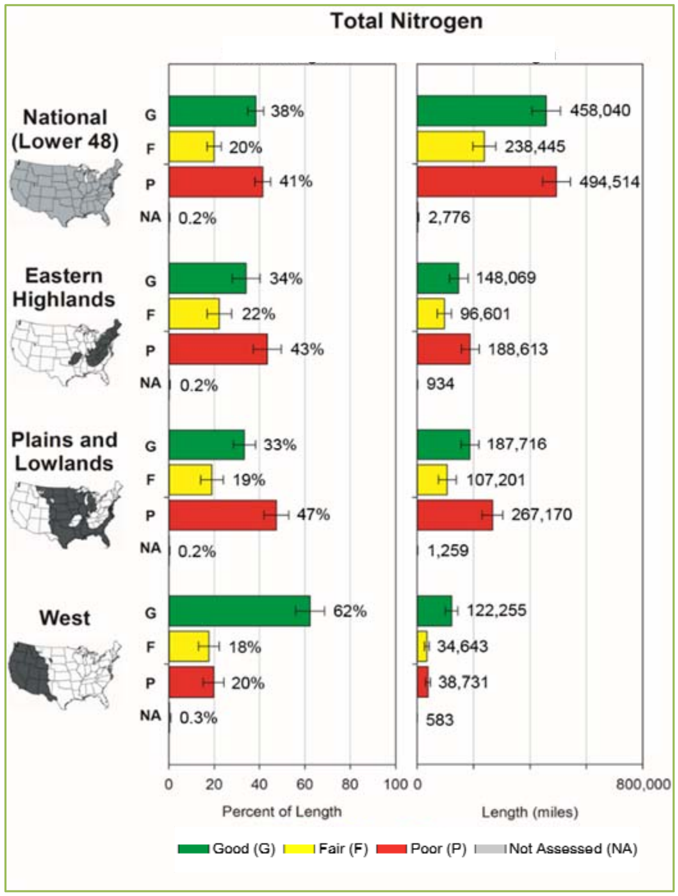


Figure 12. Total nitrogen concentrations in the nation's rivers and streams (EPA/NRSA). Percentages of river and stream length in good, fair or poor condition for nitrogen are compared to least-disturbed regional reference sites.

Salinity

Salts can be toxic to freshwater plants and animals and can make water unsafe for drinking, irrigation and livestock watering. Excess salinity can occur in areas where evaporation is high and exacerbated by repeated use of water for irrigation or water withdrawals; where road de-icers are applied; and in mining, oil drilling and wastewater discharges. Conductivity (a measure of water's ability to pass an electrical current) was used as a measure of salinity for this study.

Findings for salinity

Salinity is not a problem in 85% of the nation's river and stream miles (1,012,939 miles) (**Figure 13**). Approximately 12% (138,942 miles) are rated fair for salinity, and 3% (38,259 miles) are rated poor. An estimated 3-4% of stream length is rated poor for salinity in all three major climatic regions.

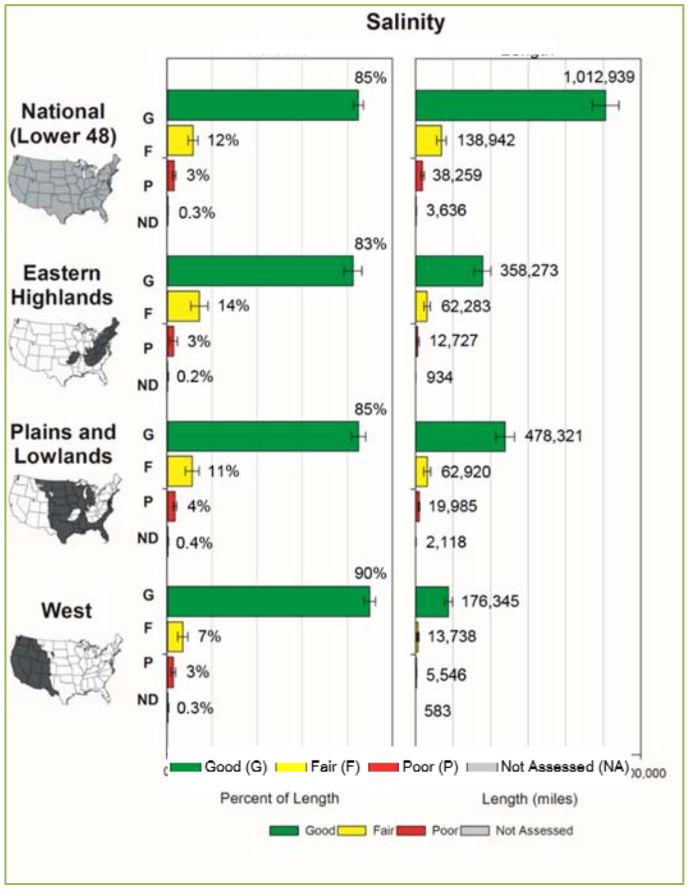


Figure 13. Salinity conditions in the nation's rivers and streams (EPA/NRSA). Thresholds are based on conditions of least-disturbed regional reference sites. Indicator is based on electrical conductivity.

Acidification

Streams and rivers can become acidic because of acid deposition (acid rain) or acid mine drainage, particularly from coal mining. Streams and rivers can also be acidic because of natural conditions, such as high levels of dissolved organic compounds. Some fish and macroinvertebrates are acid-sensitive and can only tolerate small changes in acidity. Acidification can also indirectly affect aquatic life by releasing toxic metals such as aluminum from soils into the water.

The NRSA identifies the extent to which flowing waters are not acidic, are naturally acidic (similar to reference conditions) or are acidic because of anthropogenic sources. This last category includes rivers and streams that are acidic due to chronic or episodic acid deposition or because of mine drainage.

Acid deposition forms when smokestack and auto emissions (primarily sulfur dioxide and nitrogen oxides) combine with moisture in the air to form dilute solutions of sulfuric acid and nitric acid. It can also occur in dry form, such as the particles that make up soot. Acid deposition on sensitive watersheds can have damaging effects on soils, vegetation and aquatic systems. To assess the effect of acid deposition on flowing waters, the NRSA relied on a measure of water's ability to buffer inputs of acids, called acid-neutralizing capacity (ANC). When ANC values fall below zero, water is considered acidic and can be either directly or indirectly toxic to aquatic life. When ANC is between 0 and 25 milliequivalents, the water is considered sensitive to episodic acidification during rainfall events. These threshold values were determined based on values derived from the National Acid Precipitation Assessment Program.

ANC can also be used to assess the acidity of waters in mining areas. Acid mine drainage occurs when water moves through mines and mine tailings, combining with sulfur released from certain minerals to form strong solutions of sulfuric acid and mobilizing toxic metals. Because mine drainage also produces very high concentrations of sulfate, when ANC values and sulfate values are low, acidity can be attributed to acid deposition; when ANC values are low and sulfate values are high acidity can be attributed to acid mine drainage.

Findings for acidification

Figure 14 shows that the vast majority of U.S. rivers and streams (99%, or 1,178,614 miles) are not affected by acidification. Anthropogenic sources in the remaining waters include acid deposition (0.1%, or 1,425 miles of river and stream length), mine drainage (0.2%, or 2,902 miles) and episodic acidity due to high runoff events (0.2%, or 2,825 miles). Approximately 0.4% (5,233 miles) of river and stream length is affected by acidity from natural sources. In the Eastern Highlands region, acid mine drainage affects 0.6% (2,391 miles) of river and stream length, and acid deposition affects 0.3% (1,425 miles). In the Plains and Lowlands region, 0.5% of river and stream length (2,825 miles) is affected by episodic acidity.

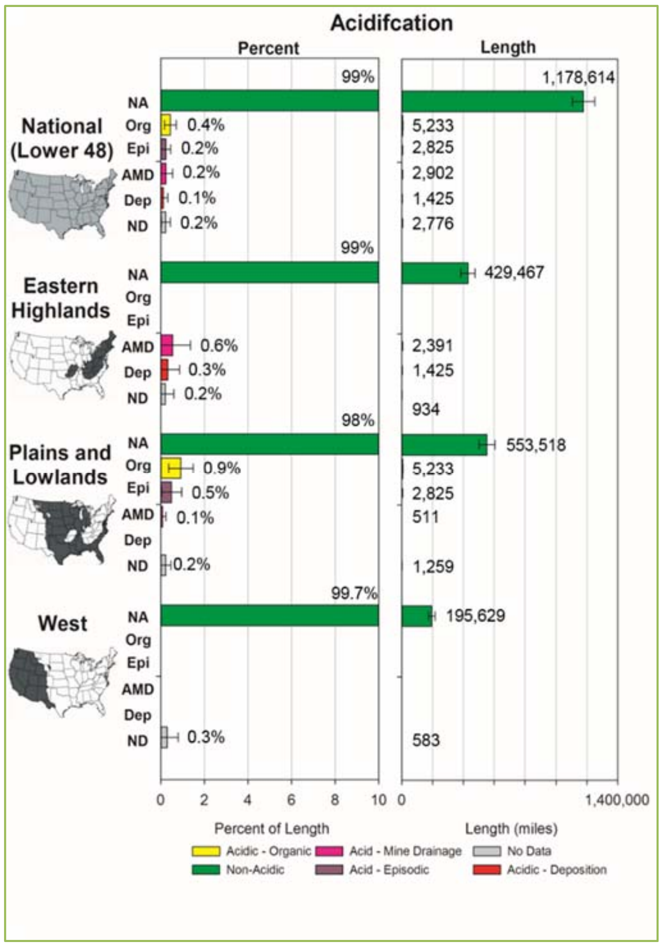


Figure 14. Acidification in the nation's rivers and streams (EPA/NRSA).

Physical habitat stressors

Among the many human activities that stress the physical condition or rivers and streams—and, by extension, fish and other aquatic organisms—are construction, certain agriculture practices, removal of vegetation buffering rivers and stream, land development and spread of impervious surfaces (e.g., roads and parking lots). The NRSA focuses on four indicators of physical habitat conditions in rivers and streams: streambed excess fine sediments, in-stream fish habitat, riparian (streamside) vegetation and riparian disturbance. These indicators help document the impact of our human footprint across the landscape as well as the progress made through widespread protection and mitigation efforts.

Excess streambed sediments

The size and shape of natural stream and river channels and the size of the particles that make up their beds reflect the interplay between sediment inputs and the flow of water. Human uses of the landscape, such as agriculture, forestry, construction, and urbanization, can increase the amount of fine sediments entering streams and rivers. The same types of land uses can also change the amount and timing of water runoff into channels, especially when they increase the amount of impervious land surfaces. Typically, these hydrologic alterations increase the frequency of high-magnitude floods, and channels can respond by down-cutting (incising), eroding their banks, and washing away important aquatic habitat. The most common response to increased fine sediment inputs is a shift to a channel formed of finer, less stable particles as these sediments are transported downstream. These excess fine sediments can fill in the habitat spaces between stream cobbles and rocks where many aquatic organisms live and breed.

For the NRSA, scientists measured the ratio between the particle size of observed sediments and the size of sediments each river or stream can move or scour during its flood stage; these measurements were taken based on measures of the size, slope and other physical characteristics of the stream channel. This ratio, also known as relative bed stability (RBS), differs naturally among regions depending on characteristics such as geology, topography, hydrology, natural vegetation and natural disturbance history. This indicator focuses on conditions indicating lower-than-expected streambed stability and higher excess sedimentation. These conditions can result from high inputs of fine sediments or increases in stormflows. Because streambed fine sediments and stability differ naturally within and among ecoregions, excess fine sediments were assessed by comparison with expected values at least-disturbed sites adjusted for factors such as geography and climate within ecoregions."

Findings for excess streambed sediments

Approximately 55% (654,401 miles) of the nation's river and stream length has streambed sediment characteristics in good condition compared to regional reference conditions (**Figure 15**). Streambed sediment characteristics are rated fair in 29% (351,774 miles) of river and stream length and poor in 15% (177,416 miles). For this indicator, the percentage of rivers and streams in the West that are in poor condition (18%, or 34,539 miles) is slightly higher than in the Eastern Highlands (15%, or 63,033 miles) and the Plains and Lowlands (14%, or 79,844 miles).

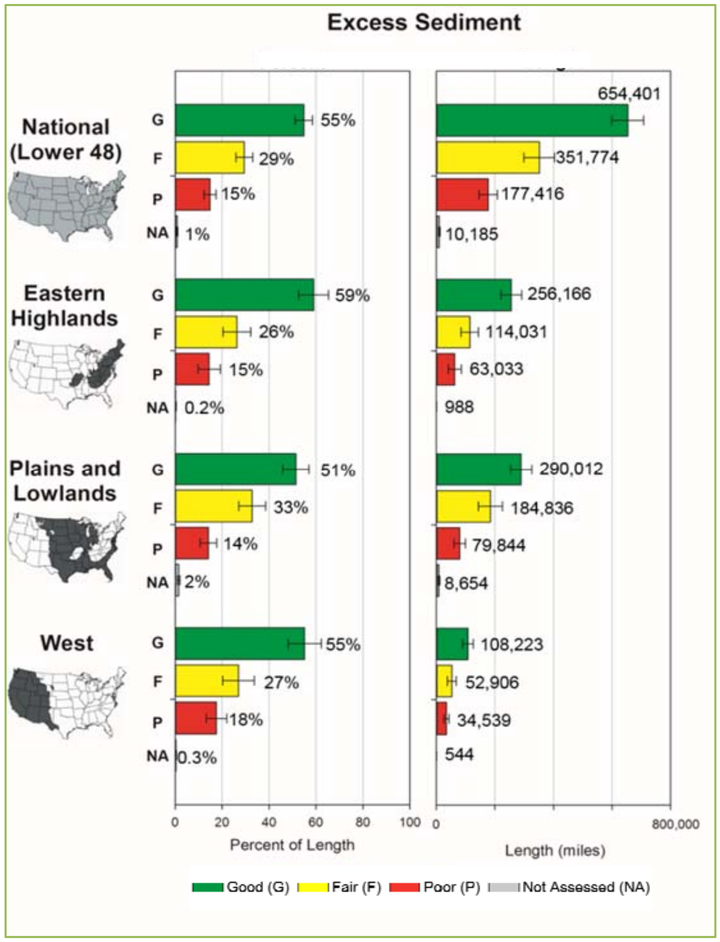


Figure 15. Excess streambed sediment in the nation's rivers and streams (EPA/NRSA).

In-stream fish habitat

The healthiest and most diverse communities of fish and macroinvertebrates are found in rivers and streams that have complex and varied forms of habitat, such as boulders, undercut banks, tree roots and logs within the stream banks. Human use of rivers and streams and their adjacent riparian areas often results in the removal or loss of much of this habitat, which in turn affects biological condition. The NRSA uses a habitat complexity measure that sums the amount of in-stream fish habitat and concealment features (such as undercut banks, boulders, large pieces of wood, brush and cover from overhanging vegetation) within the water body and its banks. Because this measure differs naturally within and among ecoregions, low in-stream fish habitat complexity was assessed by comparing it with expected values across reference condition adjusted for factors such as geography and climate within ecoregions.

Findings for in-stream fish habitat

Compared to least-disturbed reference condition, 68% (817,474 miles) of the nation's river and stream length is in good condition for in-stream fish habitat, 20% (239,830 miles) is in fair condition, and 11% (136,472 miles) is in poor condition (**Figure 16**). Of the major climatic regions, the highest proportion of river and stream length in poor condition for in-stream habitat is in the Plains and Lowlands, where 15% (84,739 miles) of river and stream length is rated poor. In the West, 10% (18,811 miles) of river and stream length is rated poor, as is 8% (32,922 miles) in the Eastern Highlands region.

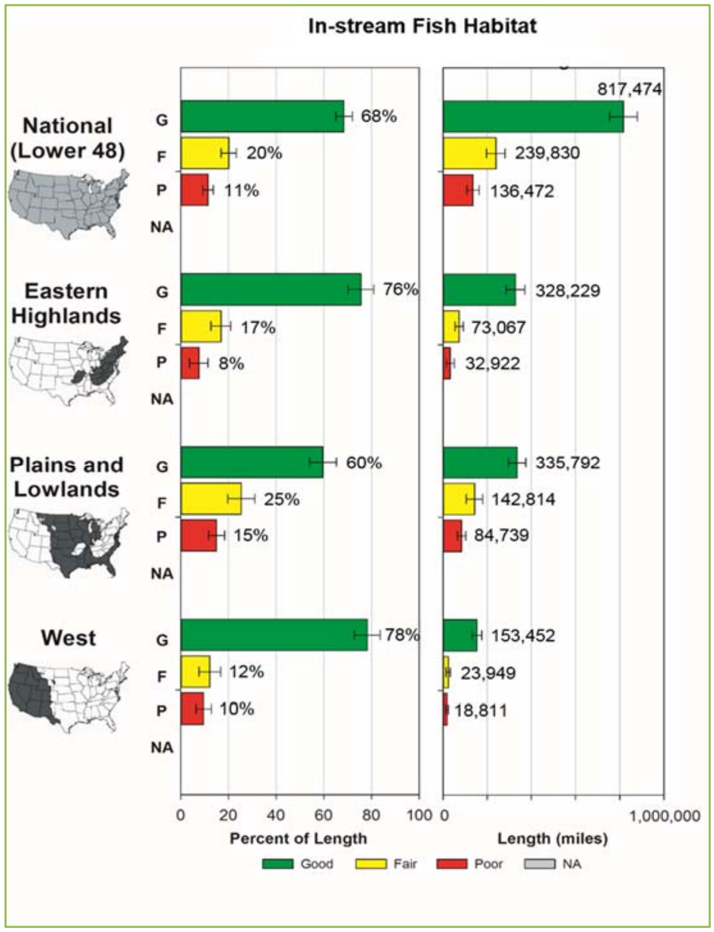


Figure 16. In-stream fish habitat in the nation's rivers and streams (EPA/NRSA).

Riparian vegetative cover

A river or stream can be buffered from the effects of human disturbance in the watershed by varied, multi-layered vegetation in the land corridor that surrounds it. Healthy, intact vegetative cover in these 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 (such as branches and logs) to serve as food, shelter and habitat for aquatic organisms. The NRSA uses a measure of riparian vegetative cover that sums the amount of cover provided by three layers of riparian vegetation: the ground layer, woody shrubs and canopy trees. Because the amount and complexity of riparian vegetation differs naturally within and among ecoregions, lower-than-expected riparian vegetative cover was assessed by comparing it with expected values across reference conditions.

Findings for riparian vegetative cover

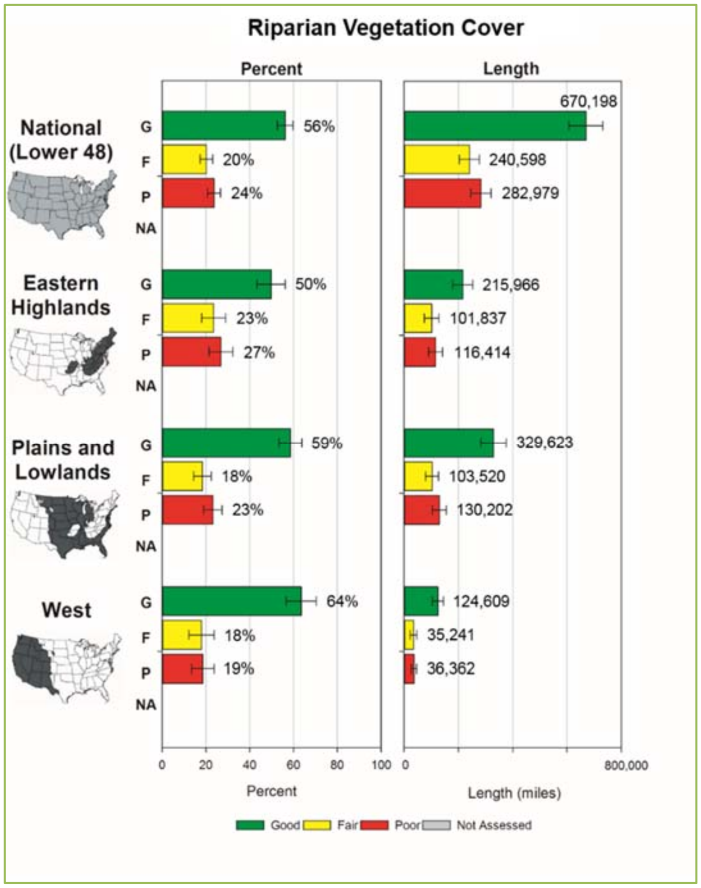


Figure 17. Riparian vegetative cover in the nation's rivers and streams (EPA/NRSA).

Over half of the nation's river and stream length (56%, or 670,198 miles) is in good condition for riparian vegetative cover compared to least-disturbed regional reference conditions (**Figure 17**). Another 20% (240,598 miles) is in fair condition, and 24% (282,979 miles) is in poor condition. The Eastern Highlands region has the highest proportion of rivers and streams with poor riparian vegetative cover (27%, or 116,414 miles), followed by the Plains and Lowlands (23%, or 130,202 miles) and the West (19%, or 36,362 miles).

Riparian disturbance

The closer human activities are to a river or stream, the more impact they will have on it. The NRSA uses a direct measure of riparian human disturbance that tallies 11 specific forms of human activities and their proximity to the river or stream in 22 riparian plots along the water body. Examples of human disturbance include roads, pavement and cleared lots, buildings, pastures and rangeland, row crops, dams and logging or mining operations. The same disturbance criteria were applied to define high, medium and low riparian disturbance in streams and rivers nationwide and were ranked in poor, fair and good condition, respectively. For example, a river or stream scored medium (i.e., in fair condition) if one type of human influence was noted in at least one-third of the riparian plots, and scored high (i.e., in poor condition) if one or more types of disturbance were observed at all of the plots.

Findings for riparian disturbance

For this indicator, 34% (411,035 miles) of the nation's river and stream length has low levels of riparian disturbance and scores in good condition, 46% (543,374 miles) has medium levels of disturbance and is rated fair, and 20% (239,366 miles) has high levels of disturbance and is rated poor (**Figure 18**). The most widespread types of riparian disturbance are roads, pastures and rangeland, and buildings. Compared to the other physical stressors discussed above, a much greater proportion of U.S. river and stream length is rated as fair (with medium levels of riparian disturbance), and a lower proportion of river and stream length is rated as good (with low levels of riparian disturbance). The three major climatic regions have similar proportions of river and stream length in the good, fair and poor categories, although the West has the highest proportion of stream length rated poor for riparian disturbance (24%, or 47,535 miles) and the lowest proportion rated good (29%, or 56,995 miles).

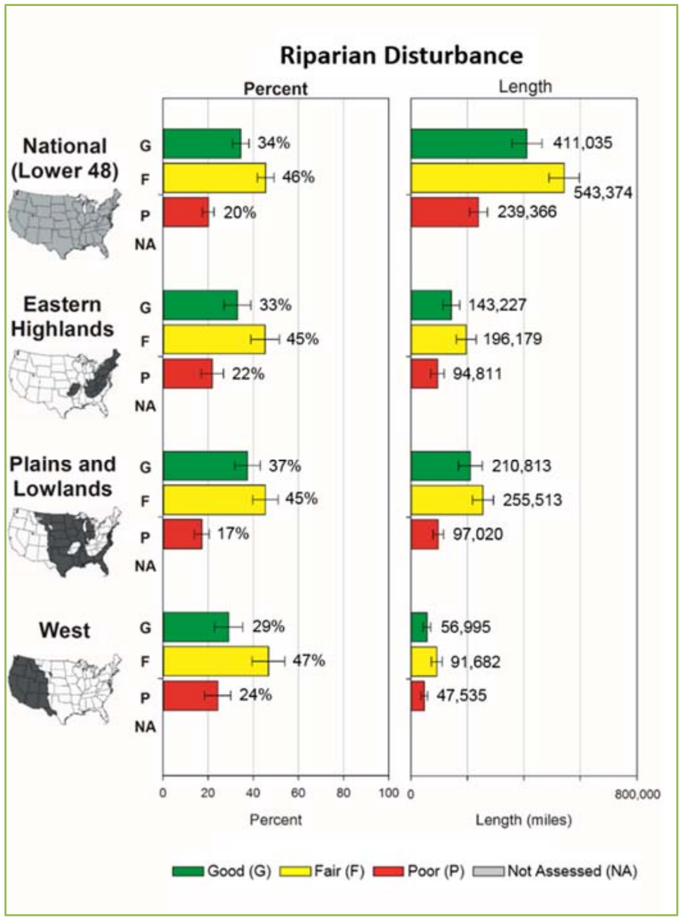


Figure 18. Riparian disturbance in the nation's rivers and streams (EPA/NRSA).

Ranking stressors: relative extent, relative risk, and attributable risk

One of the key roles of the NRSA, and of all assessments in this series, is to provide perspective on key stressors affecting the biological condition of our waters. This includes estimating the benefits that might be derived if those stressors were reduced.

For the NRSA, analysts use three approaches to assess the influence of stressors on the ecological condition of the nation's rivers and streams: relative extent, relative risk and attributable risk. Throughout this section, stressors are assessed and reported on independently and as such do not sum to 100%. Most rivers and streams are likely to experience multiple stressors simultaneously, which can result in cumulative or overlapping effects not accounted for in this analysis.

Riparian disturbance, (Photo courtesy of Liz Smith, Kansas DHE.)

Relative extent

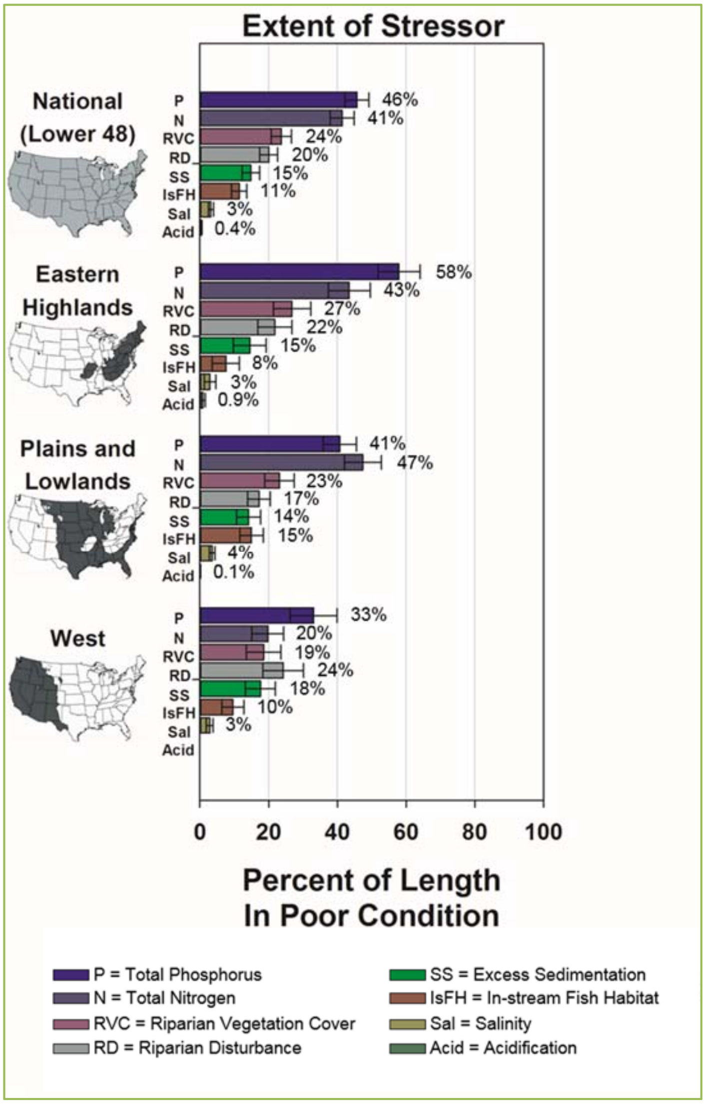


Figure 19. Relative extent of stressors in the nation's rivers and streams (EPA/NRSA).

Water resource managers need to consider how extensive a stressor is when setting priority actions at national, regional and state scales. Relative extent compares the percent of waters rated poor for each individual stressor. Most stressors can be found in all geographic areas, but those that are not pervasive do not have high relative extents.

Nationally, the most widespread stressors measured as part of the NRSA are phosphorus and nitrogen (**Figure 19**). Phosphorus levels are rated poor compared to least-disturbed conditions in 46% of river and stream length; nitrogen is rated poor in 41% of river and stream length. Riparian vegetative cover is rated poor in 24% of river and stream length, and riparian disturbance is rated poor in 20%. With a few exceptions, the extent of these stressors shows a similar pattern across the three major climatic regions.

Relative risk

Relative risk is a way to examine the severity of the impact of a stressor when it occurs. Relative risk is used frequently in the human health field. For example, a person who smokes is 15 to 30 times more likely to get lung cancer or die of lung cancer than a person who does not.[2] Similarly, scientists can examine the likelihood of finding poor biological conditions in a river or stream when phosphorus concentrations are high relative to the likelihood when phosphorus concentrations are low. When these two likelihoods are quantified, their ratio is called the relative risk. A relative risk value of 1 means that poor biological conditions are just as likely when the stressor is high as when it is low or moderate—in essence, no demonstrable effect. A relative risk of 2, however, means poor biological conditions are twice as likely when a stressor is high.

Crew members taking physical habitat measurements, (Photo courtesy of Tetra Tech, Inc.)

Results of the relative risk analyses for NRSA are presented in the middle panels of **Figure 20** and **Figure 21**. Relative risk differs between macroinvertebrates and fish, which is expected because these groups of organisms respond differently to stressors. For macroinvertebrates nationally, the relative risks are largest for excess sedimentation, total phosphorus and total nitrogen, all in the range of 1.9 to 2.0. In other words, when these stressors occur in excess levels, streams and rivers are nearly twice as likely to have poor macroinvertebrate communities as when these stressors are low or moderate. The relative risks posed by the various stressors differ in the three major climatic regions, with the West showing the most sensitivity to all the stressors compared to the other regions. In the West, macroinvertebrate communities are 2.3 to 4.8 times more likely to be in poor condition when stressors are at excessive levels compared to when they are at low or moderate levels.

The pattern of relative risk values for fish differs from macroinvertebrates. Nationally, the values of relative risk range from 1.3 to 1.8 and the values range from 1 to 2.3 for the climatic regions.

[2] Centers for Disease Control. Lung cancer: Risk factors. www.cdc.gov/cancer/lung/basic_info/risk_factors.htm (accessed November 7, 2012).

Attributable risk

Attributable risk represents the magnitude or importance of a potential stressor and can be used to help rank and set priorities for policymakers and managers. Attributable risk is derived by combining relative extent and relative risk into a single number for ranking purposes (see third panels of **Figure 20** and **Figure 21**). Conceptually, attributable risk provides an estimate of the proportion of poor biological conditions that could be reduced if high levels of a particular stressor were eliminated. This number is presented in terms of the length in poor condition that could be improved—that is, moved from poor into either the good or fair condition from poor.

For example, as noted above, phosphorus occurs at excess levels in 46% of river and stream length. Rivers and streams are almost twice as likely to have poor conditions for macroinvertebrates when phosphorus is high (relative risk of 1.9). Relative extent and relative risk combined result in an attributable risk level of approximately 30%. That is, if phosphorus levels were reduced, one might expect to see macroinvertebrates in 30% of the river and stream length improve from poor condition to good or fair condition, i.e., 14% of the total stream miles (30% of 46% of miles in poor condition for macroinvertebrates). For fish, the attributable risk is 25% nationally meaning 25% of rivers and streams might see improvements in fish health if phosphorus were reduced below "poor." In the West, no sites were assessed as acidic so the relative extent, relative risk and attributable risk values are all zero.

Some stressors can have fairly large relative risk but small attributable risk (regardless of biological community) because the relative extent of this problem is small. For example, national relative risk levels for salinity are between 1.6 (for macroinvertebrates) and 1.8 (for fish), yet excess salinity occurs in only 3% of river and stream length nationally. Therefore, the resulting attributable risk levels are small.

Attributable risk is not intended as an absolute "prediction" of the improvement in flowing waters but rather an estimate calculated in a consistent manner for all stressors so that they can be ranked relative to one another. There is no difference between the way attributable risk is interpreted and used in the human health field compared with this application for aquatic resources. We believe this to be an important tool in setting policy directions just as it is in human health discussions.

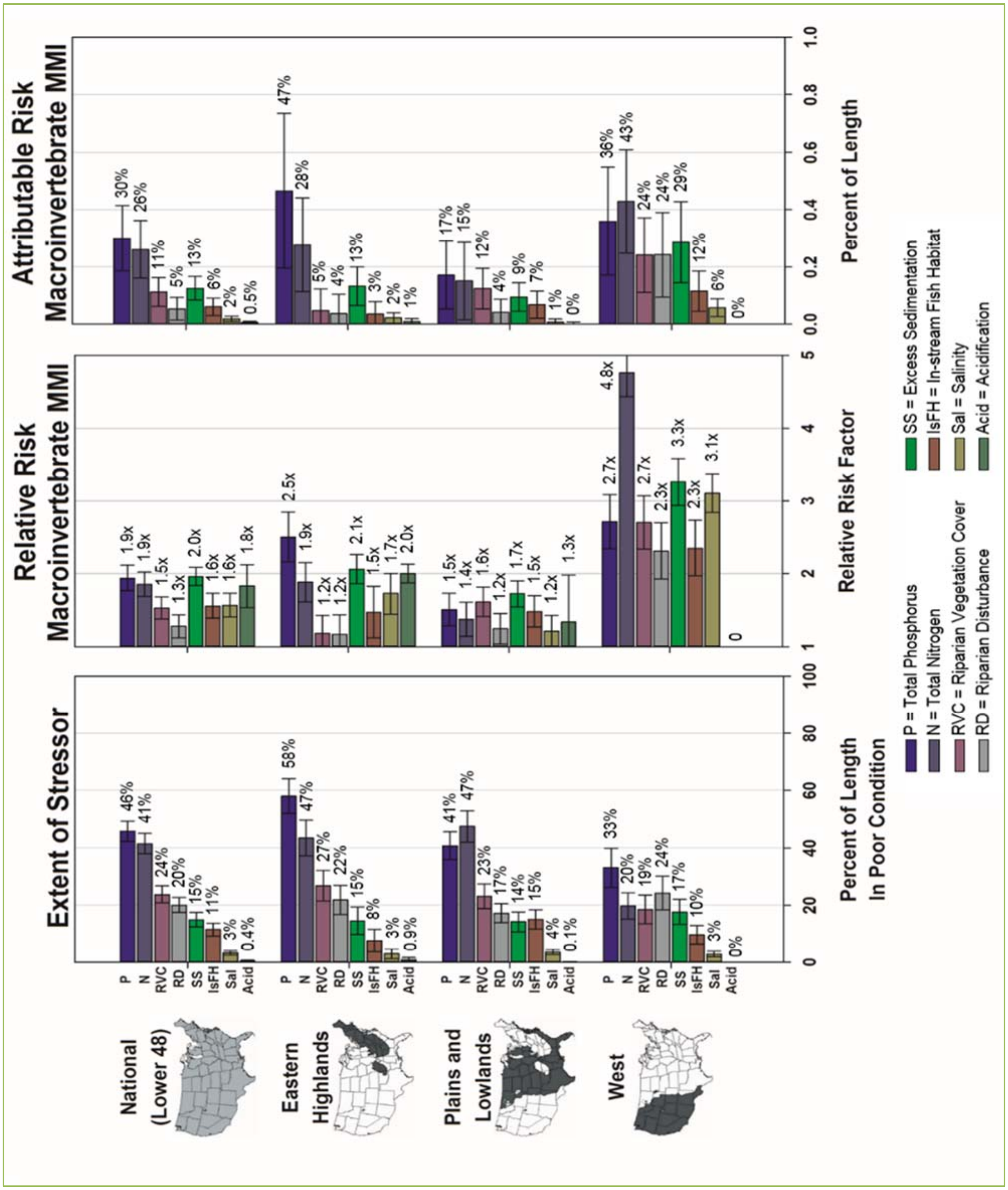


Figure 20. Relative extent, relative risk, and attributable risk to macroinvertebrates based on the macroinvertebrate MMI (EPA/NRSA).

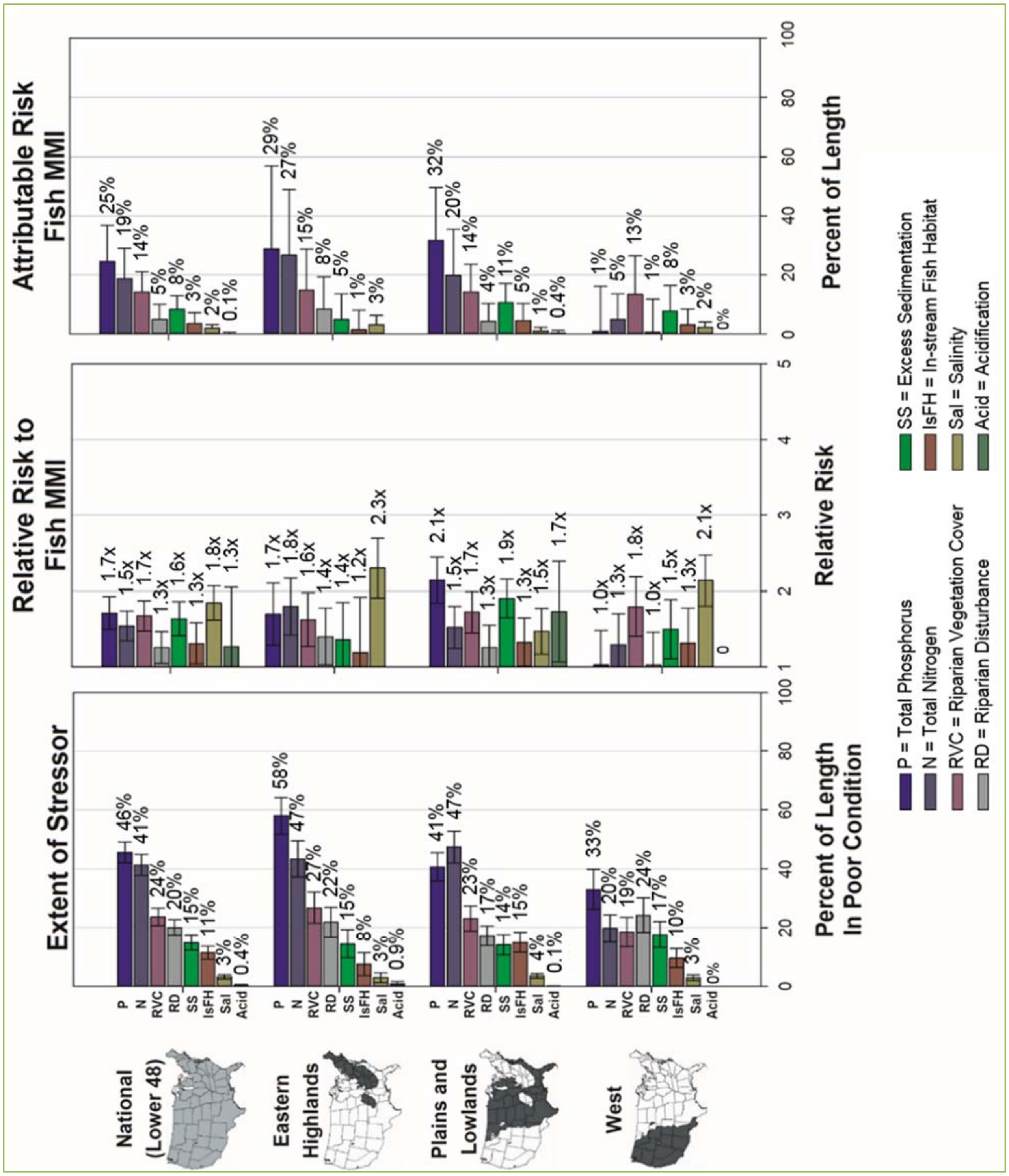
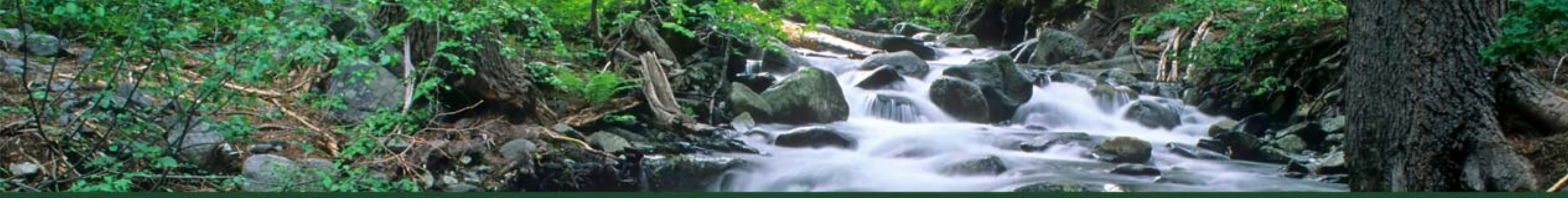


Figure 21. Relative extent, relative risk, and attributable risk to fish based on the Fish MMI (EPA/NRSA).



Chapter 4. Human Health Considerations in the Nation's Rivers and Streams

Background

In addition to physical, chemical and biological indicators of the condition of the nation's rivers and streams, the NRSA includes two indicators that provide insight into potential risks to human health: mercury in fish tissue and the pathogen indicator enterococci.

Most human exposure to mercury is through the consumption of fish. When pregnant women, nursing mothers and women who might become pregnant eat fish with mercury concentrations above specified thresholds for human protection more frequently than recommended by local advisories, this poses a neurodevelopmental health risk to fetuses, babies and young children. States issue consumption advisories for specific fish species and water bodies when state or local sampling results indicate elevated mercury concentrations. More information on fishing advisories is available from local health agencies and at http://www.epa.gov/fish-tech.

Enterococci are indicators of the presence of fecal material in water and, therefore, of the possible presence of disease-causing bacteria, viruses and protozoa. These pathogens can sicken swimmers and others who use rivers and streams for recreation or eat raw shellfish or fish.

The NRSA results are not intended to represent the full range of pollutants in rivers and streams that might adversely affect human health.

Mercury in fish tissue

Mercury is widely distributed in the environment due to both natural processes and human activities. It enters the atmosphere from the natural degassing of the earth's crust (e.g., from volcanic action) and from some industrial sources such as coal-burning power plants and hazardous waste incineration. Once in the atmosphere, it can circulate widely and be deposited on land and in water through rain and snow.

Microorganisms in water convert inorganic mercury to a toxic form of organic mercury called methylmercury. Methylmercury accumulates in fish, primarily in muscle tissue. Nearly all fish contain traces of mercury, and the amount of mercury measured in fish tissue usually increases with fish age and size. It also varies among fish species—those that prey on other fish typically accumulate higher concentrations of mercury than those that eat insects or other aquatic organisms. Measuring mercury levels in fish is critical because about 80% of all fish consumption advisories currently in effect involve mercury. Human health effects can include damage to the immune and nervous systems; developing embryos are particularly at risk.

For the NRSA, field sampling teams applied consistent methods to collect fish from 542 randomly selected river segments (fifth-order or larger) distributed across the lower 48 states. These 542 sites are a subset of the total sites sampled for the NRSA. The teams also collected additional fish at about 10% of the sites to evaluate field sampling variability. Each sample was a composite, consisting of multiple adult fish of the same species and similar size. Field teams selected fish species that people commonly eat, including largemouth and smallmouth bass, walleye, and various trout and catfish species. Fish fillet contaminant levels were then compared to EPA's human health screening values.

EPA analyzed the NRSA fish tissue samples for total mercury in addition to other contaminants. Following EPA guidance, scientists made the conservative assumption that all mercury is present in fish tissue as methylmercury. The human health screening value used to interpret mercury concentrations in fillet tissue is 0.3 milligrams of methylmercury per kilogram of tissue (wet weight) or 300 parts per billion, which is EPA's tissue-based water quality criterion for methylmercury. This threshold represents the concentration that, if exceeded, can be harmful to human health.

The fish tissue results presented here for mercury were published in Chemosphere (Wathen et al., 2015). For a wide variety of additional chemicals (including selenium, pesticides, polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs), analyses are complete and results will be presented in future publications.

Findings for mercury in fish tissue

The human health fish tissue indicator focuses on fifth-order and larger rivers. This sub-population contains 106,247 river miles, representing 9% of the total NRSA river and stream miles associated with all flowing waters (1,193,775 miles). The NRSA limits the target population to fifth-order and larger rivers because of resource constraints and the need to focus the assessment on waters that would likely support a population of fish of the size that are typically sought for human consumption. Given that levels of mercury in fish tissue vary but tend to increase with size and trophic level, this focus is intended to address both fish taken for subsistence and for sport fishing and produce assessment results that are comparable across all the waters sampled. The sampled population is the portion of the target sub-population for which we can determine whether mercury levels are above or below the human-health-based screening value. The sampled population, 49% of the target sub-population, represents 51,663 river miles. Mercury levels in the other 51% of the target sub-population (54,584 river miles) cannot be assessed because sites could not be sampled due to a variety of factors, including inability to obtain permits, lack of suitable fish, insufficient time to collect fish samples and denial of access to sites.

All fillet samples analyzed for the NRSA contain quantifiable levels of mercury. Fish tissue results indicate that 13,144 river miles have concentrations above the

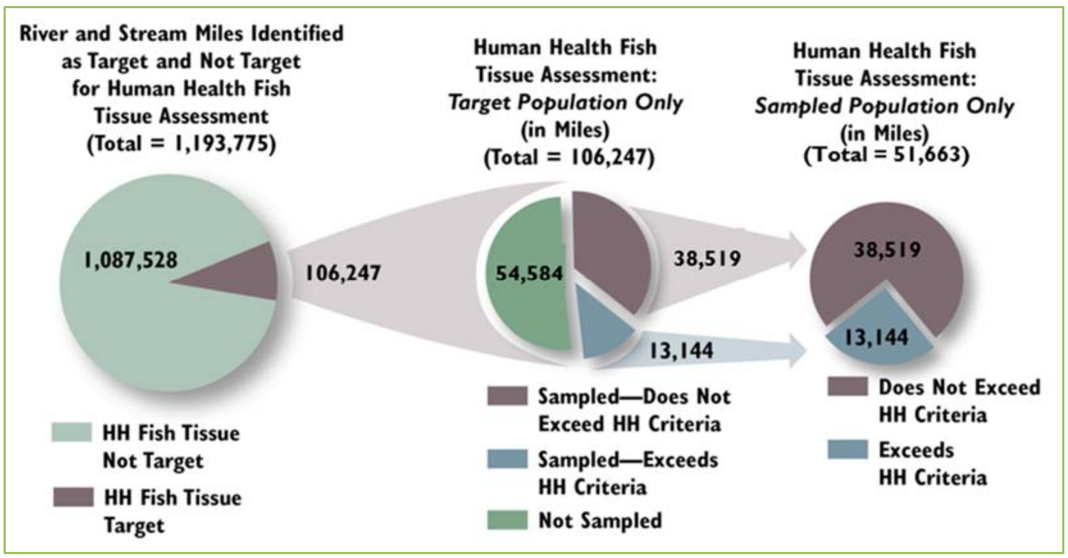


Figure 22. Human health (HH) fish tissue assessment for target (middle graphic) and sampled populations (right graphic) of the nation's rivers (EPA/NRSA). The fish tissue target population (106,247 miles of fifth order and larger rivers) is a subset of the overall NRSA population for all other indicators. No assessment can be made for the 54,584 miles of the target population that were not sampled, and the fish tissue target population assessment cannot be extrapolated to the entire rivers and streams target population. The fish tissue sampled population assessment (right graphic, 51,663 miles) cannot be extrapolated to either the entire rivers and streams target population or the fish tissue target population.

300 parts per billion human-health-based water quality criterion for mercury; 38,519 river miles do not. **Figure 22** summarizes the target and sampled populations for the fish tissue indicator.

In the Eastern Highlands, 3,419 river miles exceed the human health screening value for mercury in fish tissue and 11,319 miles do not. In the Plains and Lowlands, the screening value is exceeded in 7,424 river miles and not exceeded in 22,315 miles. In the West, 2,301 miles exceed the screening value and 4,885 miles do not exceed it. Particularly in the West and the Plains and Lowlands, a high percentage of river length was not sampled for mercury in fish tissue. Results from the sampled sites cannot be extrapolated to these unassessed waters. **Figure 23** shows the percentage of rivers in each of the three regions that were sampled for mercury in fish tissue ranging from 67% in the Eastern Highlands to 27% in the West.

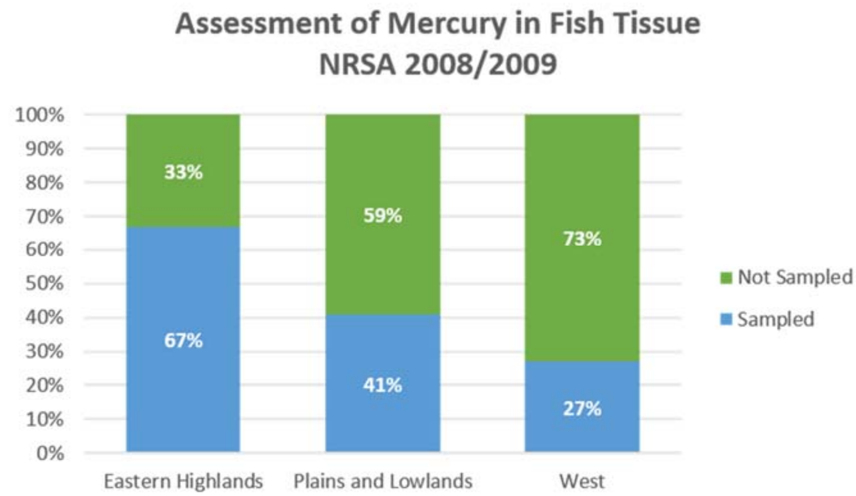


Figure 23. Percentage of fish tissue target population sampled for mercury in fish tissue in the three major climatic regions of the U.S. (EPA/NRSA).

Pathogen indicators (enterococci)

Enterococci are bacteria that live in the intestinal tracts of warm-blooded animals, including humans, and therefore indicate possible contamination of streams and rivers by fecal waste. Enterococci are typically not considered harmful to humans, but their presence in the environment indicates that other disease-causing agents such as viruses, bacteria and protozoa may also be present. Epidemiological studies conducted at beaches affected by human sources of fecal contamination have established a relationship between the density of enterococci in ambient waters and the elevated incidence of gastrointestinal illness in swimmers. Other potential health effects include diseases of the skin, eyes, ears and respiratory tract. Eating fish or shellfish harvested from waters with fecal contamination can also result in human illness. Significant economic losses can occur due to beach closures, swimming and boating bans, and closures of fishing and shellfishing areas due to fecal contamination.

Sources of fecal indicator bacteria such as enterococci include wastewater treatment plant effluent, leaking septic systems, stormwater runoff, sewage discharged or dumped from recreational boats, domestic animal and wildlife waste, improper land application of manure or sewage, and runoff from manure storage areas, pastures, rangelands and feedlots. There are also natural, non-fecal sources of fecal indicator bacteria, including plants, sand, soil and sediments, that contribute to a certain background level in ambient waters and vary based on local environmental and meteorological conditions. In some situations, background levels of fecal indicator bacteria can be high but not necessarily indicate human health risks. Watershed-scale sanitary investigations can provide important context to fecal bacteria monitoring results.

For the NRSA, water samples were analyzed using a process known as quantitative polymerase chain reaction, or qPCR, a methodology that facilitates the detection of DNA sequences unique to the selected bacteria. Analysts compared the NRSA results to a new EPA qPCR threshold for protecting human health in ambient waters designated for swimming (1,280 calibrator cell equivalents per 100 milliliters).

Findings for enterococci

Approximately 71% (841,497 miles) of the nation's river and stream length is in good condition for enterococci (i.e., samples do not exceed the threshold level) (**Figure 24**). An estimated 23% (277,593 miles) is in poor condition, with samples that exceed the threshold level. Six percent (74,686) of river and stream length has not been assessed for enterococci or has no data. NRSA sampling

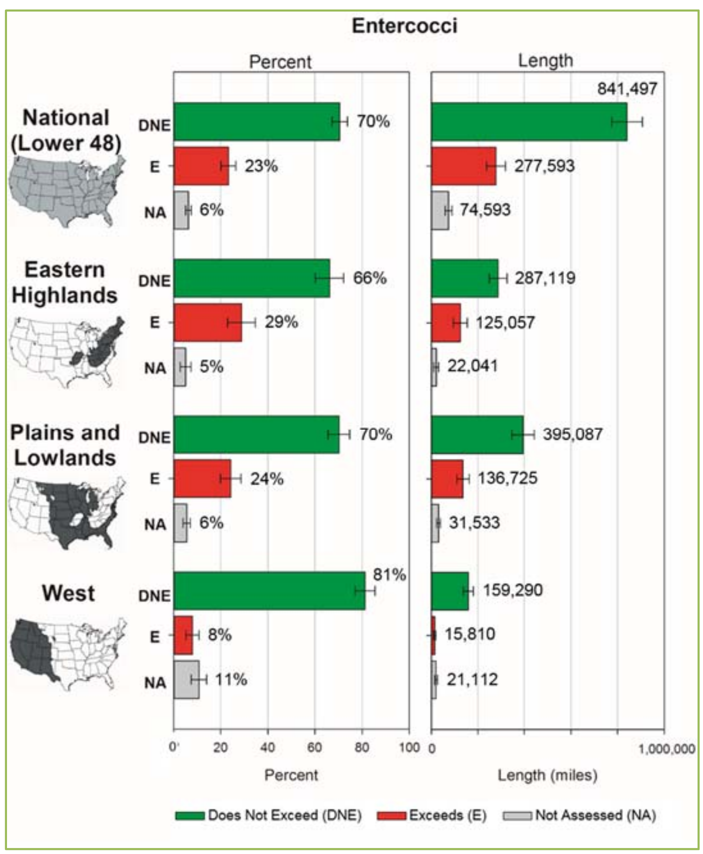


Figure 24. Enterococci human health thresholds exceedances in the nation's rivers and streams (EPA/NRSA). Percentage of rivers and streams length exceeding or not exceeding EPA human health thresholds for enterococci.

is generally conducted under base (normal) flow conditions; enterococci levels may be higher during or shortly after high flow events such as rainstorms.

Of the three major climatic regions, the Eastern Highlands region has the highest percentage of stream length exceeding the threshold (29%, or 125,057 miles), followed by the Plains and Lowlands (24%, or 136,725 miles). In the West, only 8% (15,810 miles) of stream length exceeds the threshold for enterococci.

Urban rivers: findings for mercury

Mercury is widely distributed in the environment through natural processes and through industrial activities, such as fossil fuel combustion (e.g., coal) and hazardous waste incineration. These activities release mercury into the atmosphere, where it can be transported for long distances before being deposited in water or on land. Once mercury is deposited in water, certain microorganisms can change it into methylmercury, a highly toxic form that builds up in fish, shellfish and animals that eat fish. Fish and shellfish are the main sources of human exposure to methylmercury. The levels of methylmercury in fish and shellfish depend on several factors, including what they eat, how long they live and how high they are in the food chain.

Mercury is typically found at detectable levels in fish tissue, and the amount of mercury measured in fish tissue usually increases with fish age and size. Fish tissue samples from 44 of the 163 urban sites assessed for mercury (26%) exceed the EPA fish-tissue-based human health water quality mercury criterion of 300 parts per billion (ppb) (see **Figure 25**). This represents 2,825 miles of the 10,911 assessed urban river miles.

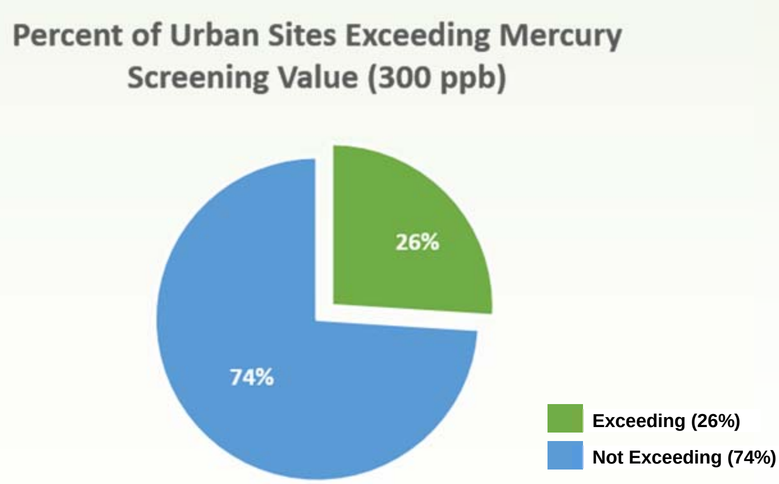


Figure 25. Mercury in fish tissue from urban sites.

Urban rivers: findings for perfluorooctane sulfonate

Perfluorinated compounds (PFCs) are artificial chemicals that persist in the environment and have been used for decades to make products that resist heat, oil, stains, grease and water. They are used in many industrial applications and are found in stain-resistant fabrics, nonstick cookware and some types of food packaging. One type of PFC, perfluorooctane sulfonate (PFOS), can accumulate to levels of concern in fish and wildlife.

PFOS is the most commonly detected PFC in the fish tissue samples. Fish tissue samples from 19 of the 162 urban sites assessed for PFCs contain PFOS above the one-meal-per-week Minnesota advisory value of 40 ppb. This represents 11% of the 10,880 assessed urban river miles, or 1,153 river miles (see **Figure 26**). To date, three states have issued fish consumption advisories based on elevated concentrations of PFOS in fish. EPA is in the process of reassessing the risk of PFOS to human health. In February 2014, EPA proposed a draft human health reference dose for PFOS that is currently under review.

Prior to the release of this report, the NRSA fish tissue results for PFCs, along with results for comparable sampling in the Great lakes in 2010, were published in Science of the Total Environment (Stahl et al., 2014).

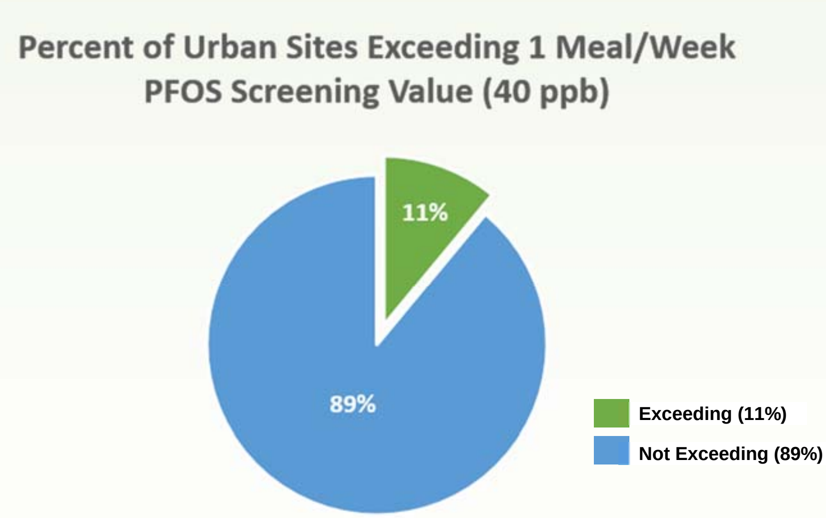
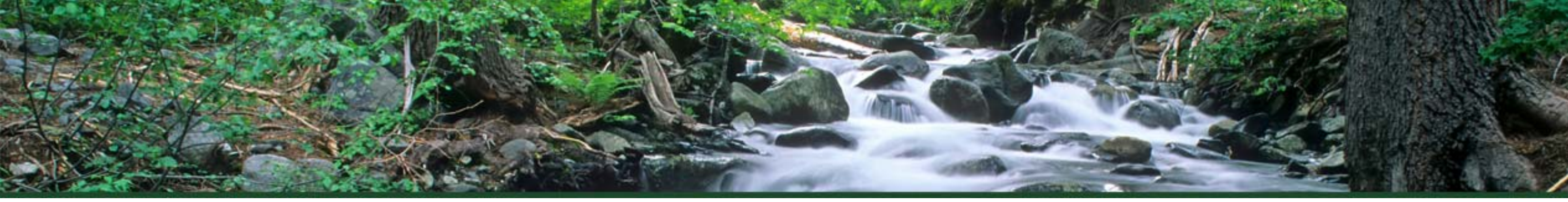


Figure 26. PFOS in fish tissue from urban sites.



Chapter 5. Changes in Stream Condition

One of the long-term goals of the NARS is detecting trends in both the condition of our aquatic resources and in the stressors that affect them. Policymakers need this information in order to evaluate whether policy decisions have been effective or a different approach is necessary to achieve important water quality goals. Trends can be tracked either at the individual water body scale or at the larger population scale.

Typically, researchers and site managers are interested in changes at individual sites, while many policymakers are more driven by changes and trends in groups or populations. Both approaches are relevant to policy-making and complement each other in evaluating trends and causes. This is analogous to human health considerations: for example, you and your doctor are interested in whether you are gaining or losing weight, but national health experts and the health policy debate will be driven more by whether there is an increase or decrease in the percentage of people in the United States who are gaining or losing weight.

To detect trends in the condition of rivers and streams, more years of data will be necessary. However, comparison of the “wadeable streams” portion of the NRSA with the 2004 WSA provides a preliminary assessment of *change* in conditions in *wadeable streams* between the two surveys. A change is not the same as a trend: it simply identifies the difference between two points in time.

Some of the changes found in streams between 2004 and 2008–2009 are statistically significant, and some are not. More data and additional analyses are necessary to fully understand what these changes are telling us.

Findings for changes in stream condition

Comparing the WSA results to the NRSA’s wadeable stream results provides an initial look at changes for six of the survey indicators—the macroinvertebrate MMI, total phosphorus, total nitrogen, in-stream fish habitat, riparian vegetative cover and riparian disturbance. Some indicators were not included in the change analysis either because they had not been evaluated in the WSA or because protocols were modified for the later study. For this change analysis, the NRSA evaluation thresholds were applied to data from both studies. Results from the WSA cannot be compared to results in other chapters of this report because the NRSA evaluates both rivers and streams, not just streams.

The figures below show the percent of stream length in good condition for a given indicator for the WSA in 2004 and the NRSA in 2008–2009. When the difference in the two estimates is statistically significant, it is noted with a red star. A detailed statistical analysis of the difference between surveys and the statistical confidence in that difference was performed and underlies the presentation of the results below. The WSA condition class percentages differ from those in the WSA report to allow comparison between the target populations of wadeable streams across the country. Minor adjustments were made to the WSA population to be comparable to the NRSA design and, when applicable, the WSA results are compared to the updated thresholds developed for NRSA.

In **Figure 27**, results for the macroinvertebrate community indicator (i.e., MMI) and nutrient indicators (phosphorus and nitrogen) are shown for the nation and the three major climatic regions. Nationally, the percent of stream length in good macroinvertebrate condition drops from 36.7% in 2004 to 27.8% in 2008–2009. This difference is statistically significant for the nation and may be driven by a 16.6% decline in streams in good condition in the Plains and Lowlands. For the Eastern Highlands, the values also decline, but the difference is not statistically significant. There is no significant difference in macroinvertebrate condition for streams in the West.

A consistent, statistically significant drop is evident in the percentage of stream length in good condition for phosphorus. Nationally, 50.7% of stream length is in good condition for phosphorus in 2004, compared to 36.4% in 2008–2009. This pattern occurs in all three major climatic regions, with a decline of approximately 15% in both the Eastern Highlands and the Plains and Lowlands, and a 12% change in the West.

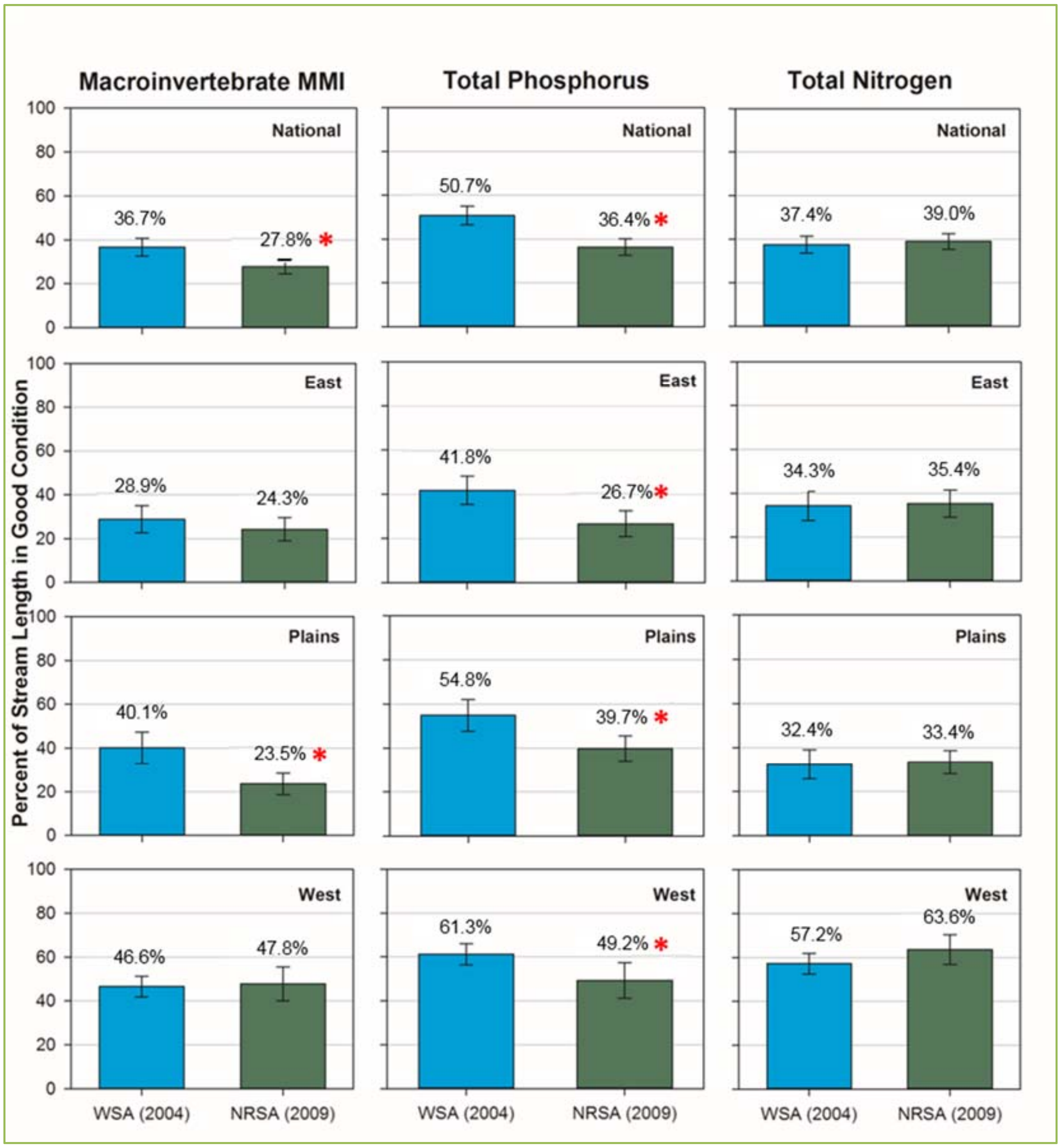


Figure 27. Change in macroinvertebrate condition and nutrients between 2004 and 2008–2009, based on percent of length in good condition (EPA/NRSA). Red stars indicate statistically significant change.

Conversely, the percent of stream length in good condition for nitrogen has risen slightly (1.6%) on a national basis, although this change is not statistically significant.

Another way to examine the nutrient information from NRSA is to consider changes across concentration levels. Differences in nutrient concentrations vary across the country due to both natural and anthropogenic factors. Tracking changes in concentration levels in addition to assessing against reference condition can be useful in understanding conditions across the country. **Figure 28** presents information on changes between streams assessed in 2004 and the NRSA 2008–2009 streams based on concentration categories for phosphorus and nitrogen. Nationally, a statistically significant change is evident across all of the concentration categories for phosphorous. The analysis shows an 11% decrease in the percent of stream length with phosphorus concentration levels below 10 µg/l. The analysis also shows an increase of 6% in stream length with phosphorus levels between 10 and 100 µg/l, an increase of 4% in stream length between 100–1000 µg/l, and an increase of 1% in stream length with levels greater than 1000 µg/l. All three major regions show statistically significant decreases in the percent of stream length with concentration levels below 10

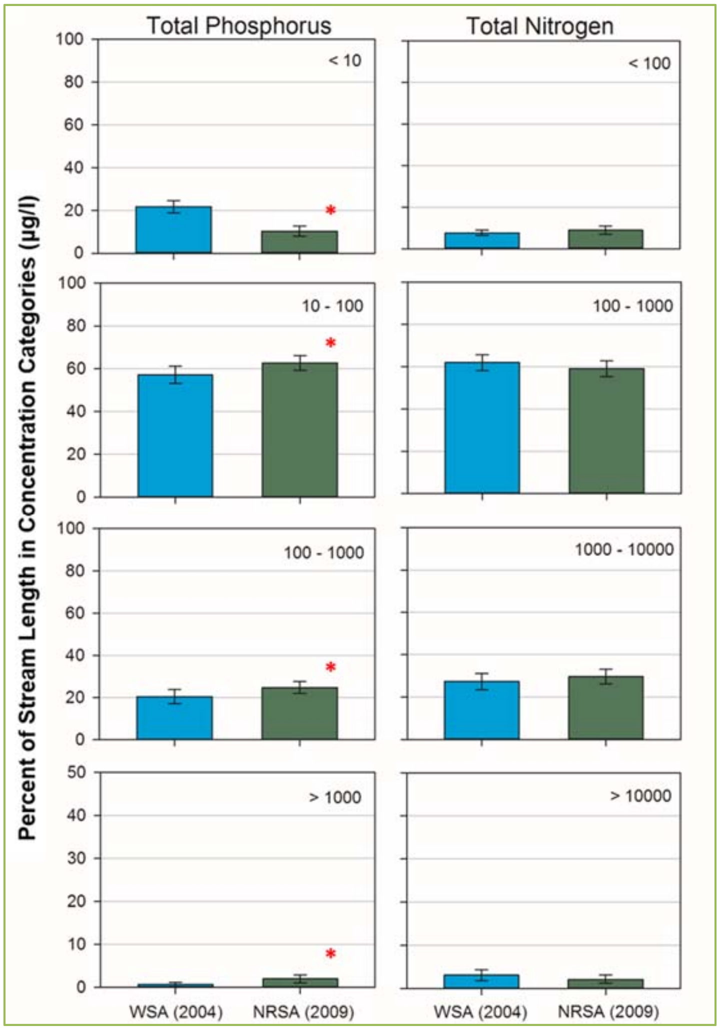


Figure 28. Total phosphorus and nitrogen concentrations in the nation's streams (EPA/NRSA). Percent of stream length in concentration categories for nutrients. Red stars indicate statistically significant change

µg/l, ranging from a 3% decrease in the Plains and Lowlands to a 16% decrease in the East and a 19% decrease in the West (not shown in the graphic).

No statistically significant change is evident in the nitrogen data at the national level, although small changes occur in the Plains and Lowlands region.

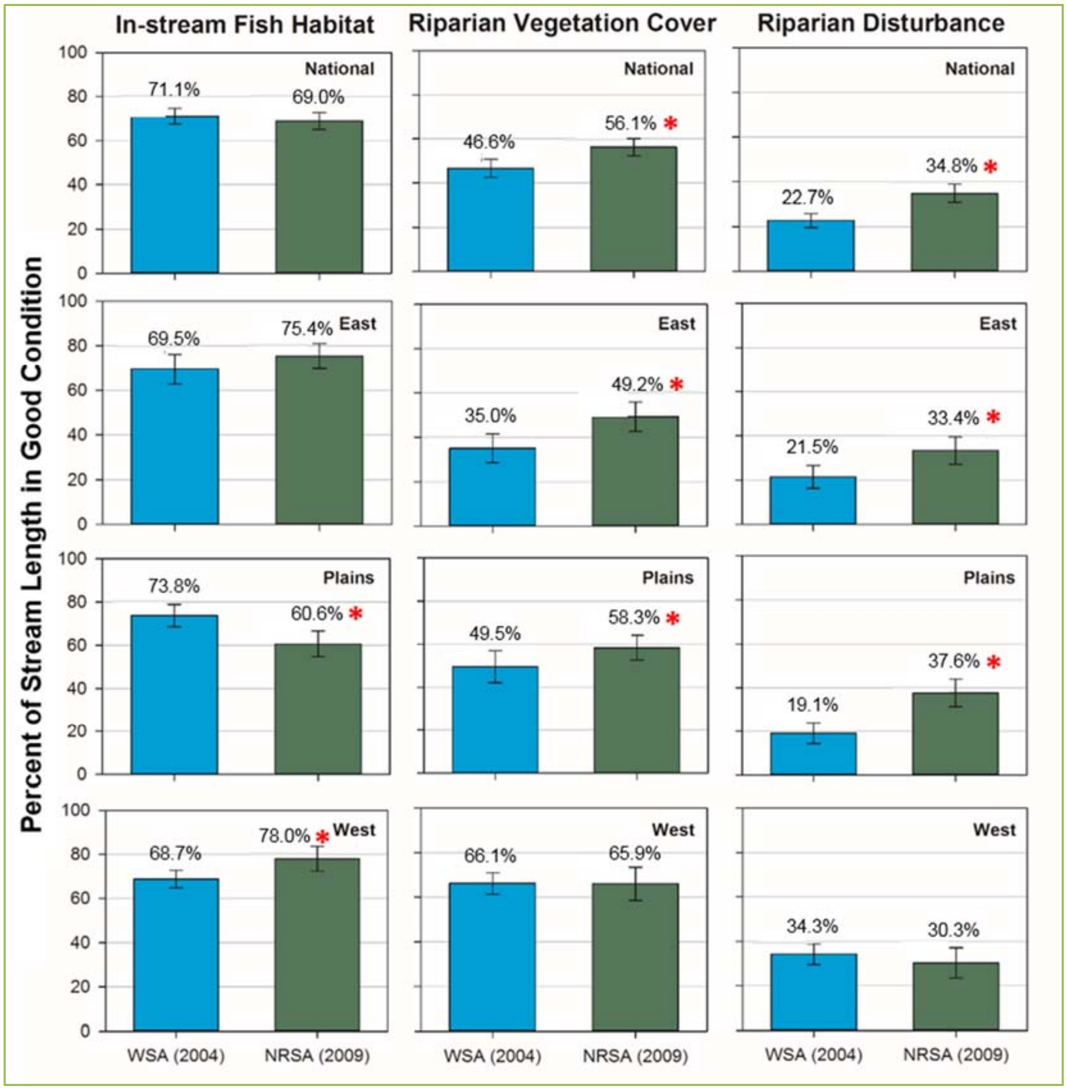
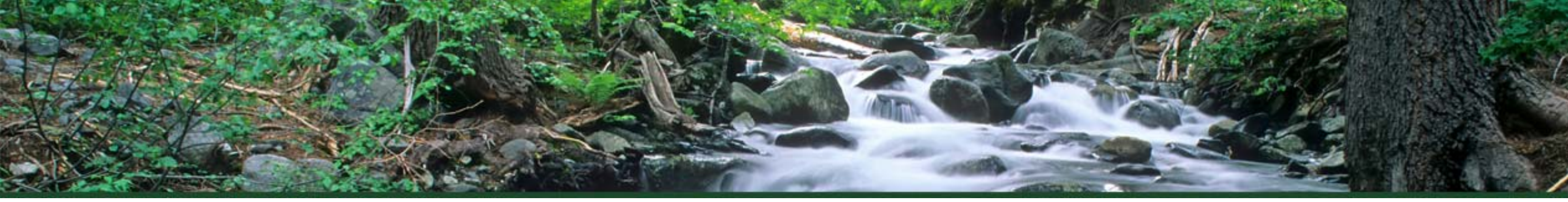


Figure 29. Change in stream fish habitat, riparian vegetation cover, and riparian disturbance between 2004 and 2008–2009 (EPA/NRSA). Percent of stream length in good condition; red stars indicate statistically significant change.

Figure 29 presents change results for three of the habitat indicators: in-stream fish habitat, riparian vegetation cover and riparian disturbance. The percent of stream length with good in-stream fish habitat did not change nationally, but it decreased significantly in the Plains and Lowlands and West regions. Nationally and in the Eastern Highlands and the Plains and Lowlands, the percent of stream length in good condition for riparian vegetation cover increased, with no statistically significant change in the West. The percent of stream length with low levels of riparian disturbance (i.e., in good condition) also shows statistically significant increases nationally, increasing from 22.7% in 2004 to 34.8% in 2008-2009, and it shows a similar increase in the Eastern Highlands and in the Plains and Lowlands region.

The statistically significant differences noted are not necessarily the result of human activities. Analysts have examined the relationships between the change in nutrients and natural phenomena such as precipitation, stream flow and drought, but they have found no reasons to explain the differences. Additional work is underway to examine relationships to other signals of natural phenomena and to signals of human activity. EPA and USGS are also examining how long-term trend data from USGS sites might help provide context for the changes between the WSA and the NRSA. Trends in water quality will emerge over time as more surveys are completed, and our understanding of the reasons for the trends will advance.

Crew member taking physical habitat measurement in small stream, (Photo courtesy of USGS.)



Chapter 6. Ecoregional Results

Introduction

Ecoregions are geographic areas that display similar environmental characteristics, such as climate, vegetation, type of soil and geology. EPA has defined ecoregions at various scales, from a continental scale (Level I) to fine scales that divide the land into smaller ecosystem units (Levels III or IV). This chapter will focus on NRSA results for the nine U.S. Level III ecoregions aggregated for use in the NARS. These nine ecoregions, shown in **Figure 30**, are:

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

Ecoregions are designed to be used in environmental assessments, for setting water quality and biological criteria, and to set management goals for pollution control. It is important to assess water bodies in their own ecological setting. For example, the rivers in the mountainous, cold-to-temperate Northern Appalachians will have many similar characteristics; they run through steep, rocky channels over glacial sediments and are influenced by annual precipitation totals of 35 to 60 inches. These rivers will differ significantly from those in the dry plains, tablelands and low mountains of the Xeric ecoregion, which drain erodible sedimentary rock and are subject to flash floods in a climate where precipitation ranges from 2 to 40 inches and average temperatures are much higher.

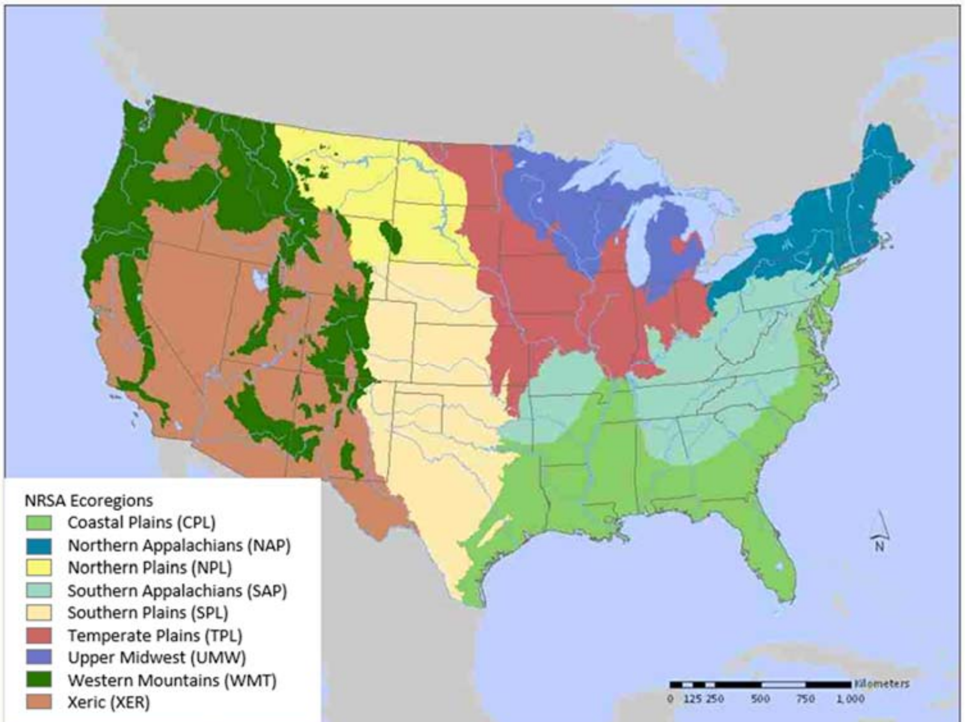


Figure 30. Ecoregions for the NRSA (EPA/NRSA).

For purposes of the NRSA, least-disturbed reference sites in each ecoregion were used to set benchmarks for good, fair and poor condition in that ecoregion and to reflect the variability within it (see Chapter 2 and the NRSA Technical Report for more information on this approach). This chapter provides nationwide comparisons of key NRSA results for the nine ecoregions. It then describes each ecoregion in more detail, providing background information and describing NRSA results for the length of rivers and streams throughout the ecoregion. These results should not be extrapolated to an individual state or water body within the ecoregion because the study was not designed to characterize conditions at these finer scales. This information also cannot be compared to the ecoregional results presented in the earlier WSA, which presented results only for streams. See Chapter 5 for the assessment of change for wadeable streams only between the WSA and the NRSA. A number of states implemented randomized designs at the state scale to characterize the condition of rivers and streams throughout their state, but these assessments are not described here.

Nationwide results

The three most widespread stressors to rivers and streams—phosphorus, nitrogen and reduced riparian vegetative cover—are depicted by ecoregion in the following maps, along with summaries of macroinvertebrate condition and enterococci levels. These maps provide an overview of how conditions, based on ecoregion-specific least-disturbed conditions, vary across the nation. Additionally, information on nutrient concentrations by ecoregion is also provided.

Biological condition — macroinvertebrate multi-metric index

Nationally, 46% of rivers and streams are in poor biological condition based on the macroinvertebrate MMI. In five ecoregions, more than 40% of the river and stream miles are rated poor for biological condition (**Figure 31**).

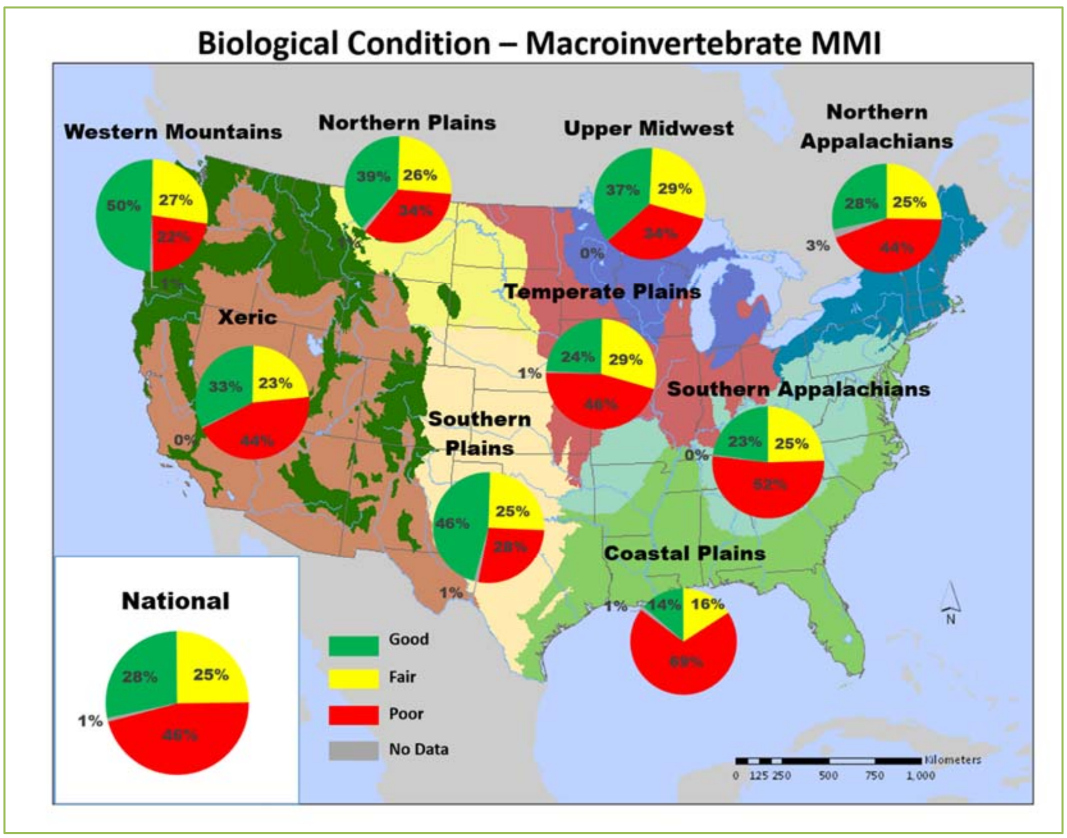


Figure 31. Biological condition in rivers and streams based on the macroinvertebrate MMI across the nine ecoregions (EPA/NRSA). Margin of error for national results is approximately ±3.5%; for the ecoregions, the margin of error ranges up to 11%, with most between ±5.5 and ±10%. Percentages may not add up to 100% due to rounding. Thresholds used to determine biological condition are based on region-specific reference condition.

Nutrients — total phosphorus and nitrogen

The nutrients phosphorus and nitrogen are the most widespread stressors of those assessed in the NRSA. **Figure 32** shows that in seven of the nine ecoregions, phosphorus levels are rated poor (i.e., high) in a third or more of river and stream miles. In three of these ecoregions, more than half of the river and stream miles are rated poor. Nationally, 46% of river and stream miles are rated poor for phosphorus.

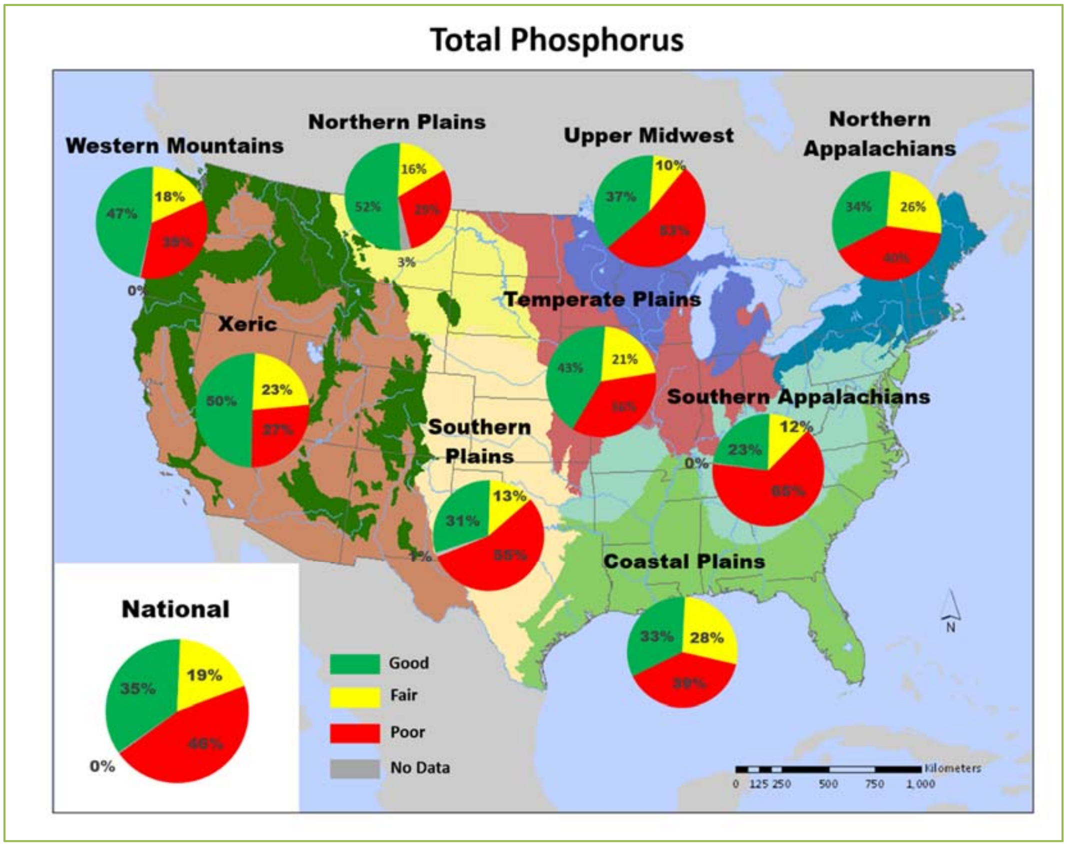


Figure 32. Total phosphorus levels in rivers and streams across the nine ecoregions (EPA/NRSA). Margin of error for national results is approximately ±3.5%; for the ecoregions, the margin of error ranges up to 12% with most between ±4.5 and ±10%. Percentages may not add up to 100% due to rounding. Thresholds used to determine phosphorus condition are based on region-specific reference sites.

Impacts for nitrogen are similar to phosphorus results in many ecoregions (**Figure 33**). In five ecoregions, nitrogen is rated poor (i.e., high) in a third or more of the river and stream miles; in one ecoregion, it is rated poor for more than 50% of rivers and streams. Nationally, 41% of river and stream miles are rated poor for nitrogen.

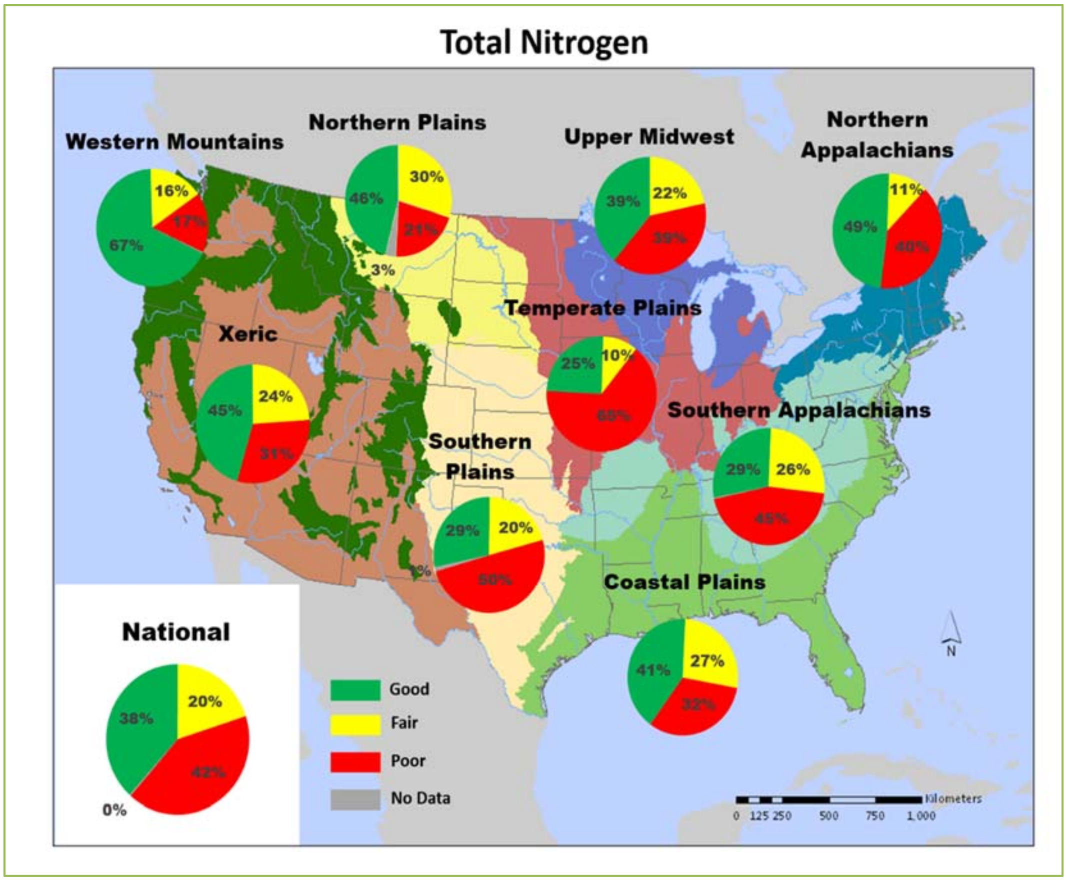


Figure 33. Total nitrogen levels in rivers and streams across the nine ecoregions (EPA/NRSA). Margin of error for national results is approximately ±3.5%; for the ecoregions, the margin of error ranges up to 12% with most between ±4.5 and ±10%. Percentages may not add up to 100% due to rounding. Thresholds used to determine nitrogen condition are based on region-specific reference conditions.

The assessment above looks at nutrients based on least-disturbed reference conditions. Another informative way to look at the NRSA nutrient results is to examine the concentration levels across the country and how they differ ecoregionally. **Figure 34** presents the percent of river and stream miles in different concentration categories for phosphorus and nitrogen.

Findings from the NRSA show that more than 50% of river and stream miles in the Temperate Plains and the Southern Plains have phosphorus concentrations at or above 100 μg/l. Nearly 90% of the river and stream miles in the Northern Appalachians and Western Mountains have phosphorus levels below 100 μg/l. A similar pattern exists for nitrogen across the ecoregions. More than 50% of river and stream miles in the Temperate Plains and the Southern Plains have nitrogen concentrations at or above 1000 μg/l, while the Northern Appalachians and Xeric ecoregions have nearly 90% of their river and stream miles below 100 μg/l.

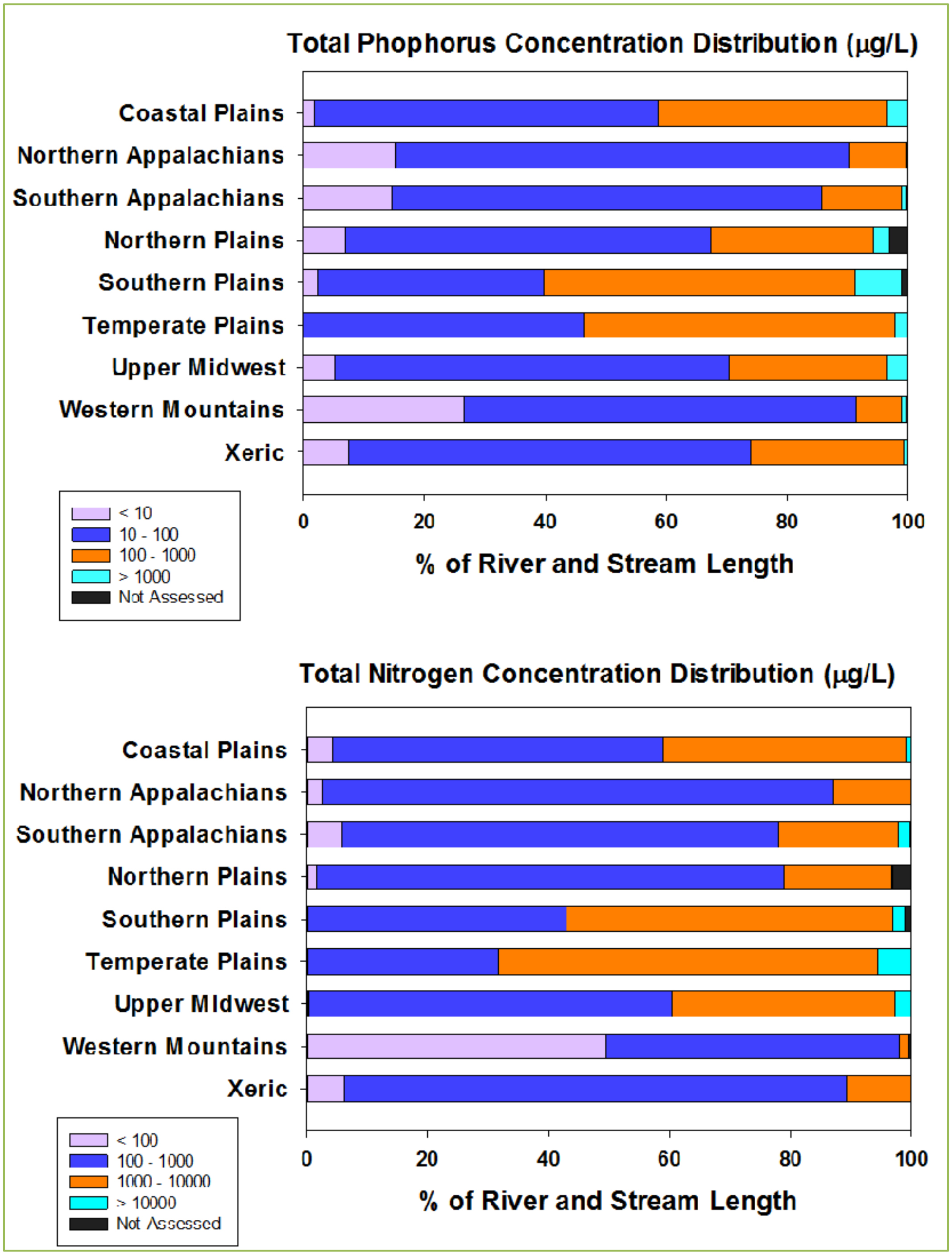


Figure 34. Distribution of nutrient concentrate categories, by each of the nine aggregate ecoregions (EPA/NRSA). Nutrient concentrations were grouped into one of four nutrient categories for both phosphorus and nitrogen.

Riparian vegetative cover

Nationally, 24% of river and stream miles are rated poor for riparian vegetation cover. In five of the nine ecoregions, a quarter or more of river and stream miles are rated poor relative to expected riparian cover (**Figure 35**).

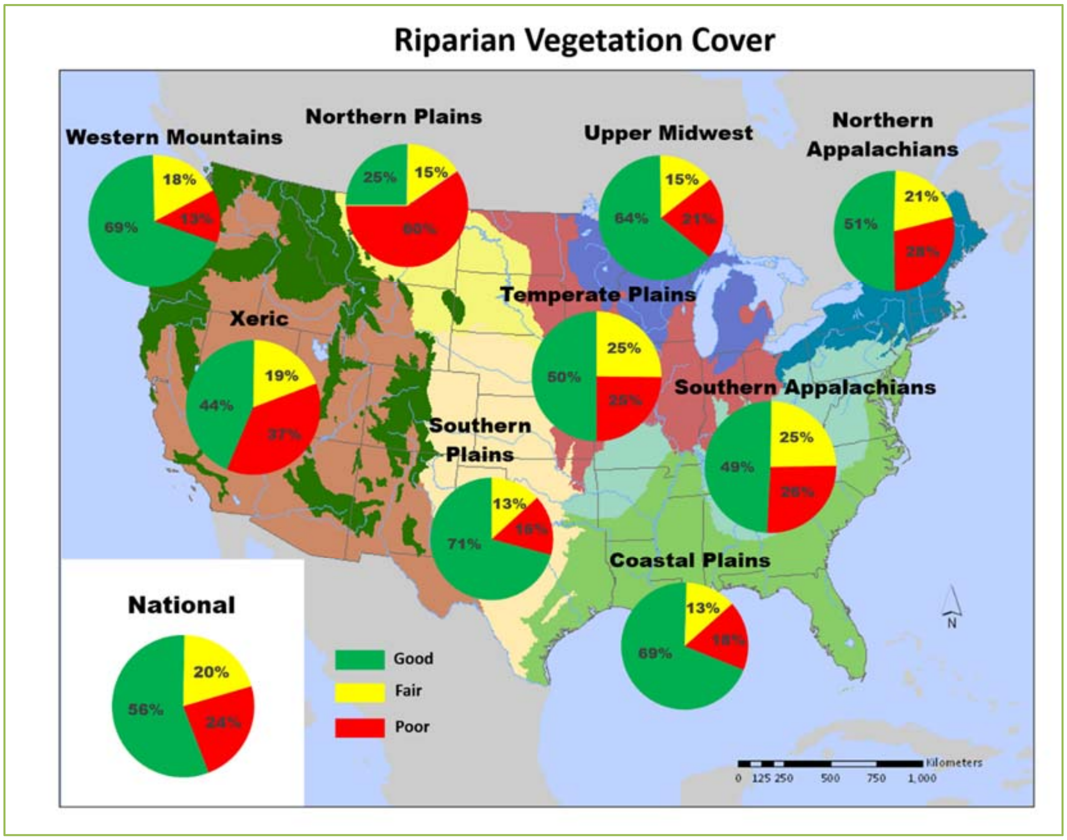


Figure 35. Riparian vegetative cover in rivers and streams across the nine ecoregions (EPA/NRSA). Margin of error for national results is approximately ±3.5%; for the ecoregions, the margin of error ranges between ±5.5 and ±11%. Percentages may not add up to 100% due to rounding. Thresholds used to determine riparian vegetative cover condition are based on region-specific reference conditions.

Enterococci

Nationally, 23% of river and stream miles exceed human health thresholds for enterococci bacteria (**Figure 36**). In five of the nine ecoregions, between 20% and 33% of miles exceed thresholds.

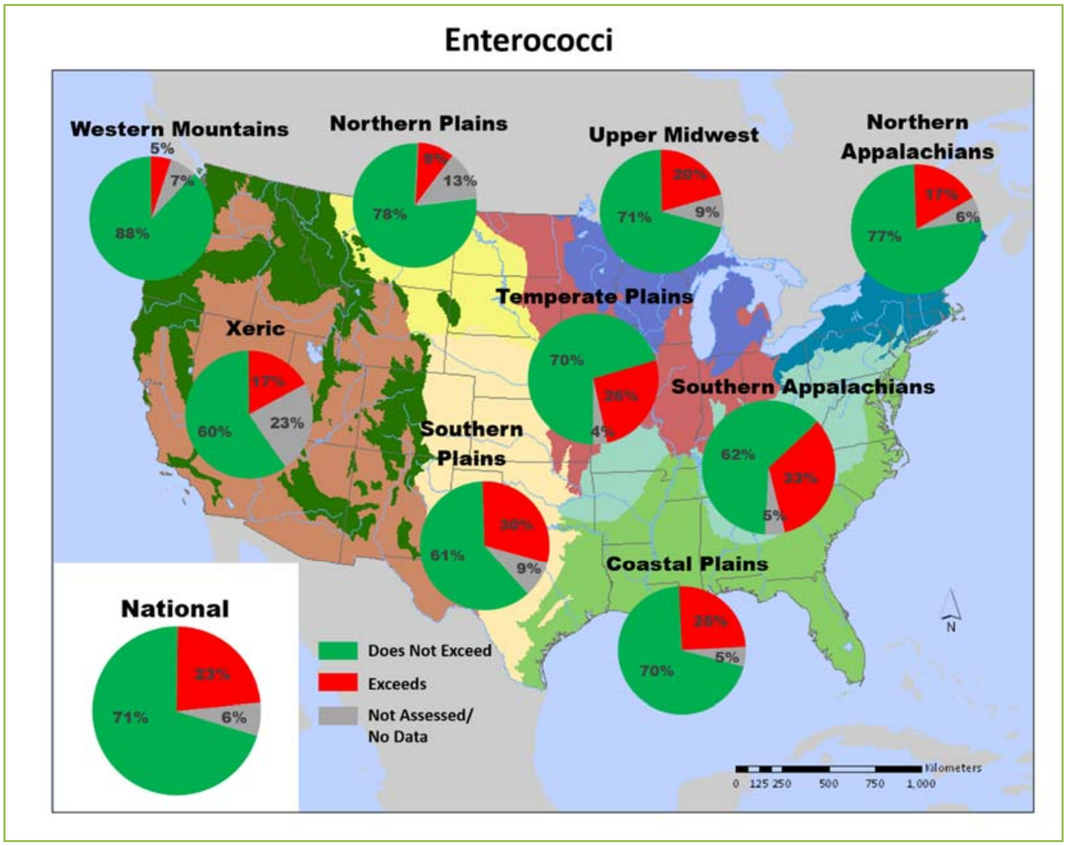


Figure 36. Enterococci human health threshold exceedance in rivers and streams across the nine ecoregions (EPA/NRSA). Margin of error for national results is approximately ±3%; for the ecoregions, the margin of error ranges between ±2 and ±11%. Percentages may not add up to 100% due to rounding.

Alaska's Yukon River Survey in the National Rivers and Streams Assessment

A 600-mile reach of the Yukon River mainstem between Fort Yukon and Kaltag, Alaska, was surveyed during the summer of 2009 as part of the NRSA (**Figure 37**). The Yukon River, or "Great River" in Gwich'in, is believed to have been the human migration route to North America. It drains approximately 330,000 square miles, is 1,980 miles in length, and is the fourth largest river basin in North America. Although this glacially fed river has had occurrences of pollution from gold mining, military activities and wastewater discharges, recent studies describe a relatively intact ecosystem.

The purpose of the survey was to conduct a water quality and habitat assessment of the Yukon River mainstem. The Alaska Department of Environmental Conservation—along with the Yukon Inter-Tribal Watershed Council, the Council of Athabascan Tribal Governments, the University of Alaska Anchorage, Koyukuk National Wildlife Refuge and USGS—conducted the survey using protocols consistent with the NRSA and USGS's *National Field Manual for the Collection of Water-Quality Data*. The Yukon River was found to have inherently unstable substrates, minimal water quality concerns, high suspended sediment loads and nitrogen levels that are not considered a limiting factor for aquatic organisms. Overall, the results were consistent with natural variability and expected conditions throughout the reach. The Yukon River Condition Summary is available from the Alaska Department of Environmental Conservation at www.dec.alaska.gov/water/wqsar/monitoring/documents/YukonReport_Final.pdf.

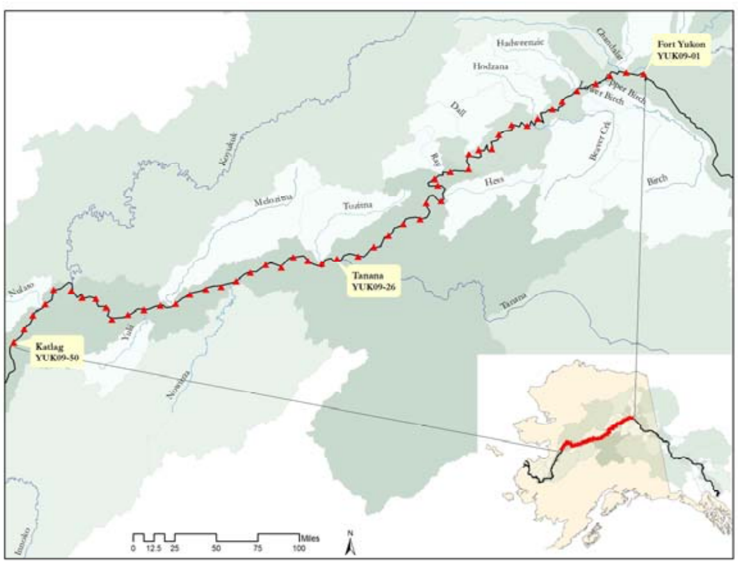


Figure 37. During the summer of 2009, 50 sites were sampled along the mainstem of the Yukon River.

Northern Appalachians

Setting

The Northern Appalachians ecoregion covers all of the New England states, most of New York, the northern half of Pennsylvania, and northeastern Ohio. Included in the ecoregion are New York's Adirondack and Catskill Mountains and Pennsylvania's Allegheny National Forest. Major river systems include the St. Lawrence, Allegheny, Penobscot, Connecticut and Hudson. The total river and stream length represented in the NRSA for the Northern Appalachians ecoregion is 117,742 miles.

Forests in this ecoregion were extensively cleared in the 18th and 19th centuries. Current fish stocks are lower than at the time of European contact, but the coastal rivers of the Northern Appalachians ecoregion still have a wide variety of fish—including shad, alewife, salmon and sturgeon—that are born in fresh water, move to the sea for most of their lives, and then return to fresh water to spawn. Major manufacturing and chemical, steel, and power production occur in the large metropolitan areas around New York City, Connecticut and Massachusetts. It is common for treated wastewater effluent to account for much of the stream flow downstream from major urban areas.

This ecoregion is generally hilly, with some intermixed plains and mountain ranges. River channels in the glaciated uplands of the northern parts of the ecoregion are steep and rocky, and they flow over glacial sediments. The climate is cold to temperate, with mean annual temperatures ranging from 39°F to 48°F. Annual precipitation totals range from 35 to 60 inches. The Northern Appalachians ecoregion covers some 139,424 square miles of land (4.6% of the conterminous United States), with about 4,722 square miles of land under federal ownership. Based on satellite images from the 2006 National Land Cover Dataset, the distribution of land cover in this ecoregion is 61% forested, 15% planted/cultivated and 9% developed; various other types of land cover (such as wetlands or scrubland) constitute the remaining 15% of the ecoregion.

Summary of NRSA findings, Northern Appalachians

A total of 199 NRSA sites were sampled to characterize the condition of rivers and streams in the Northern Appalachians ecoregion. **Figure 38** shows an overview of the findings.

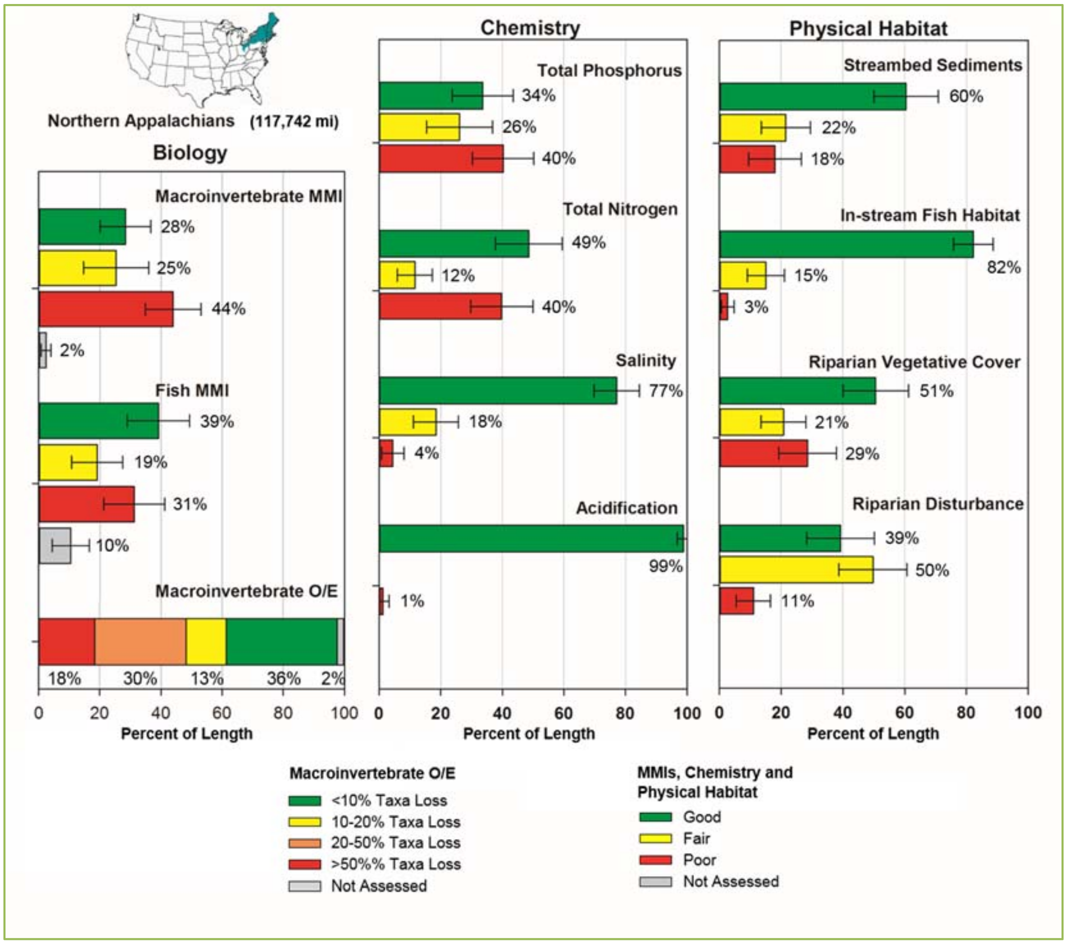


Figure 38. NRSA survey results for the Northern Appalachians ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

Biological condition

The macroinvertebrate MMI shows that 44% of the river and stream length in the Northern Appalachians ecoregion is in poor condition, 25% is in fair condition, and 28% is in good condition. The macroinvertebrate O/E taxa loss results show that 18% of river and stream length has lost more than 50% of taxa expected to occur, and 30% has lost between 20% and 50% of expected taxa.

The fish MMI shows that 31% of river and stream length in this ecoregion is in poor condition. Ten percent of river and stream length is not assessed or, for various reasons, has insufficient data to calculate the fish MMI.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Northern Appalachians ecoregion are phosphorus, nitrogen, riparian vegetative cover, streambed sediments and riparian disturbance. Compared to least-disturbed conditions for this ecoregion:

- Phosphorus is at high levels (rated poor) in 40% of river and stream length, medium levels (rated fair) in 26%, and low levels (rated good) in 34%.

- Nitrogen is at high levels (rated poor) in 40% of river and stream length, medium levels (rated fair) in 12%, and low levels (rated good) in 49%.

- Riparian vegetative cover is rated poor in 29% of river and stream length, fair in 21%, and good in 51%.

- Streambed sediments are rated poor in 18% of river and stream length, fair in 22%, and good in 60%.

- Riparian disturbance is at high levels (rated poor) in 11% of river and stream length, medium levels (rated fair) in 50%, and low levels (rated good) in 39%.

Southern Appalachians

Setting

The Southern Appalachians ecoregion stretches over ten states, from northeastern Alabama to central Pennsylvania, and includes the interior highlands of the Ozark Plateau and the Ouachita Mountains in Arkansas, Missouri and Oklahoma. The topography of this ecoregion is mostly hills and low mountains, with some wide valleys and irregular plains. Its land area covers about 321,900 square miles (11% of the conterminous United States), with about 42,210 square miles in federal ownership. Many significant public lands, including the Great Smoky Mountains National Park, the George Washington and Monongahela National Forests and Shenandoah National Park, are located within this ecoregion.

The Southern Appalachians ecoregion has some of the greatest aquatic animal diversity of any area of North America, especially for species of amphibians, fishes, mollusks, aquatic insects and crayfishes. Some areas, such as the Great Smoky Mountains National Park, continue to protect exceptional stands of old-growth forest riparian systems. Nevertheless, the effects of habitat fragmentation, urbanization, agriculture, channelization, diversion, mining and impoundments have altered many rivers and streams in this ecoregion.

Rivers in this ecoregion flow mostly over bedrock and other resistant rock types, with steep channels and short meander lengths. A number of major rivers originate here, including the Susquehanna, James and Potomac, along with feeders into the Ohio and Mississippi River systems, such as the Greenbrier River in West Virginia. The total river and stream length represented in the NRSA for the Southern Appalachians ecoregion is 316,476 miles. It is considered temperate wet, with annual precipitation of about 40 to 80 inches and mean annual temperature ranging from 55°F to 65°F. Based on satellite images in the 2006 National Land Cover Dataset, this ecoregion is 60% forested, 23% cultivated and 9% developed; the remaining 8% is in various other types of land cover.

Summary of NRSA findings, Southern Appalachians

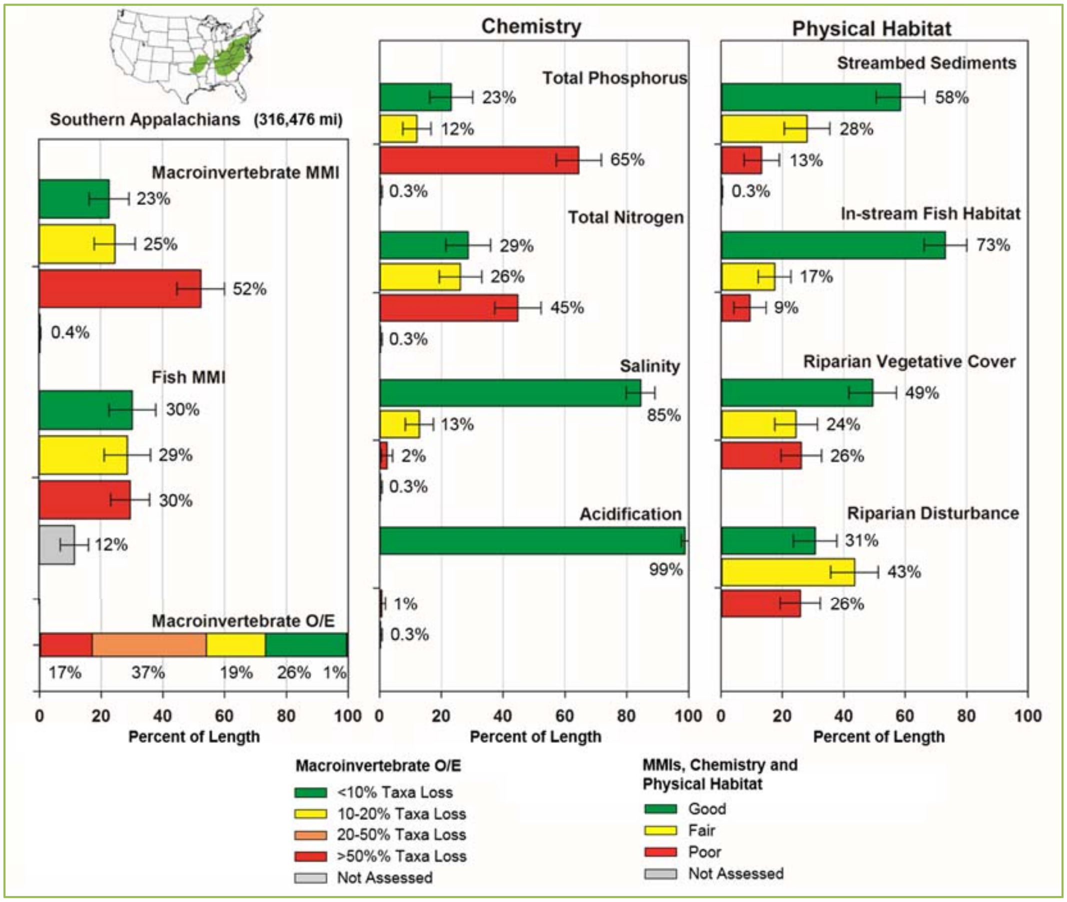


Figure 39. NRSA survey results for the Southern Appalachian ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

A total of 321 NRSA sites were sampled to characterize the condition of rivers and streams in the Southern Appalachians ecoregion. An overview of the findings is shown in **Figure 39**.

Biological condition

The macroinvertebrate MMI shows that 52% of the river and stream length in the Southern Appalachians ecoregion is in poor condition, 25% is in fair condition, and 23% is in good condition. The macroinvertebrate O/E taxa loss results show that 17% of river and stream length has lost more than 50% of taxa expected to occur, and 37% of river and stream length has lost between 20% and 50% of expected taxa.

The fish MMI shows that 30% of river and stream length is in poor condition. Twelve percent of river and stream length is not assessed or, for various reasons, has insufficient data to calculate the fish MMI.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Southern Appalachians ecoregion are phosphorus, nitrogen, riparian vegetative cover, riparian disturbance and streambed sediments. Compared to least-disturbed conditions for this ecoregion:

- Phosphorus is at high levels (rated poor) in 65% of river and stream length, medium levels (rated fair) in 12%, and low levels (rated good) in 23%.
- Nitrogen is at high levels (rated poor) in 45% of river and stream length, medium levels (rated fair) in 26%, and low levels (rated good) in 29%.
- Riparian vegetative cover is in poor condition in 26% of river and stream length, fair in 24%, and good in 49%.
- Riparian disturbance is at high levels (rated poor) in 26% of river and stream length, medium levels (rated fair) in 43%, and low levels (rated good) in 31%.
- Streambed sediments are rated poor in 13% of river and stream length, fair in 28%, and good in 58%.

Coastal Plains

Setting

The Coastal Plains ecoregion covers all of Florida, eastern Texas and the Atlantic seaboard from Florida to New Jersey. It includes the Mississippi Delta and Gulf Coast, and it ranges north along the Mississippi River to the Ohio River. The total land area of this ecoregion is about 395,000 square miles, or 13% of the conterminous United States. Of this area, 25,890 square miles, or 7%, is in federal ownership. River systems within or intersecting the Coastal Plains ecoregion include the Mississippi, Suwannee, Savannah, Potomac, Delaware, Susquehanna, James, Sabine, Brazos and Guadalupe.

River habitats in the Coastal Plains ecoregion have high species richness and the greatest number of endemic species of aquatic organisms in North America. These organisms include fish, aquatic insects and mollusks, as well as unique species such as paddlefish, American alligators and giant aquatic salamanders. However, it is estimated that about 18% of the aquatic species in this ecoregion are threatened or endangered. Historically, this ecoregion had extensive bottomlands that flooded for several months; these areas are now widely channelized and confined by levees. Acid mine drainage, urban runoff, air pollution, sedimentation and the introduction of invasive (i.e., non-native) species have affected riparian habitats and native aquatic fauna.

In general, rivers in the Coastal Plains meander broadly across flat plains created by river deposition and form complex wetland topographies, with natural levees, back swamps and oxbow lakes. Typically, they drain densely vegetated watersheds; well-developed soils and moderate rains and subsurface flows keep suspended sediment levels in the rivers relatively low. An exception is the Mississippi River, which carries large sediment loads from dry lands in the central and western portion of its drainage area. The total river and stream length represented in the NRSA for the Coastal Plains ecoregion is 176,510 miles.

The topography of this ecoregion is mostly flat plains, barrier islands, many wetlands and about 50 important estuary systems that lie along its coastal margins. The climate is temperate wet to subtropical, with average annual temperatures ranging from 50°F to 80°F and annual precipitation ranging from 30 to 79 inches. Based on satellite images in the 2006 National Land Cover Dataset, the distribution of land cover in this ecoregion is 28% forested, 26% cultivated, 21% wetlands and 9% developed, with the remainder in various other types of land cover.

Summary of NRSA findings, Coastal Plains

A total of 308 NRSA sites were sampled to characterize the condition of rivers and streams in the Coastal Plains ecoregion. An overview of the findings is shown in **Figure 40**.

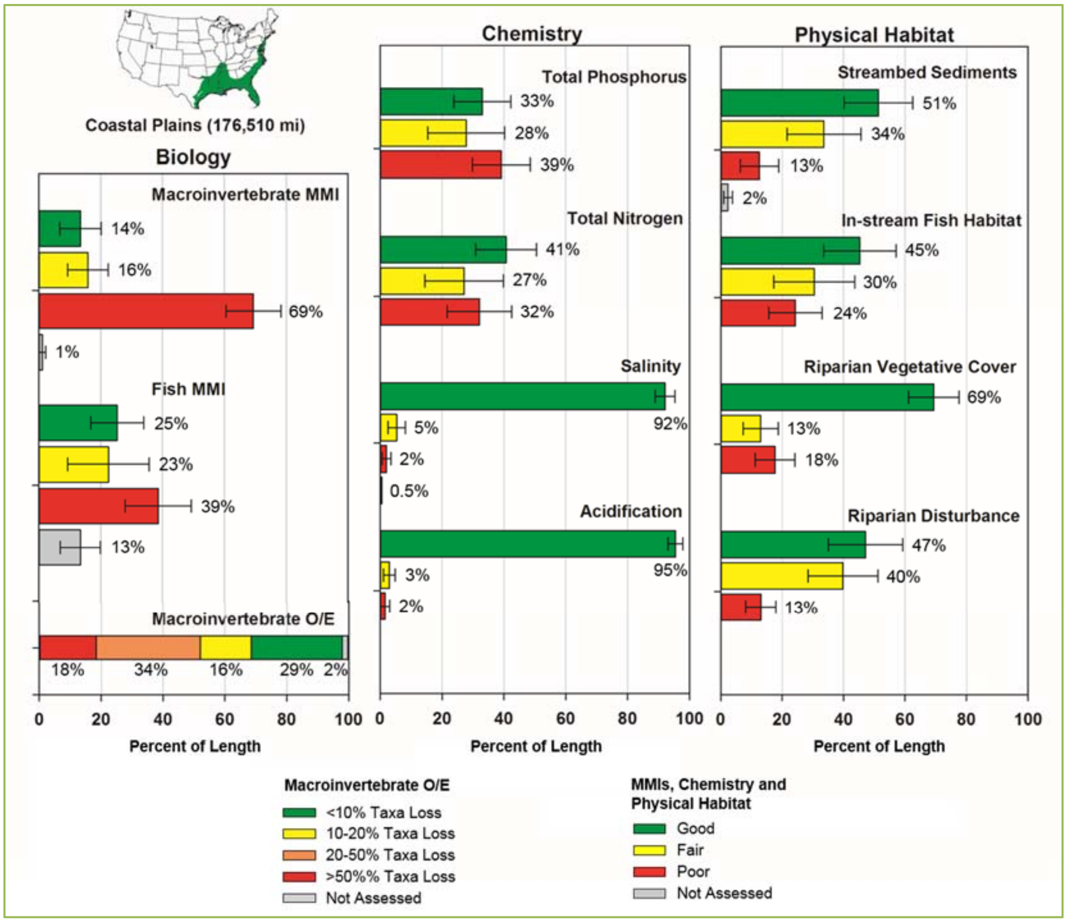


Figure 40. NRSA survey results for the Coastal Plains ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

Biological condition

The macroinvertebrate MMI shows that 69% of river and stream length in the Coastal Plains ecoregion is in poor condition compared to least-disturbed conditions, 16% is in fair condition, and 14% is in good condition. The macroinvertebrate O/E taxa loss results show that 18% of river and stream length has lost more than 50% of the taxa expected to occur, and 34% of river and stream length has lost between 20% and 50% of expected taxa.

The fish MMI shows that 39% of river and stream length is in poor condition. Thirteen percent of river and stream length is not assessed or, for various reasons, has insufficient data to calculate the fish MMI.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Coastal Plains ecoregion are phosphorus, nitrogen, in-stream fish habitat, riparian vegetative cover and riparian disturbance. Compared to least-disturbed conditions for this ecoregion:

- Phosphorus is at high levels (rated poor) in 39% of river and stream length, medium levels (rated fair) in 28%, and low levels (rated good) in 33%.
- Nitrogen is at high levels (rated poor) in 32% of river and stream length, medium levels (rated fair) in 27%, and low levels (rated good) in 41%.
- In-stream fish habitat is in poor condition in 24% of river and stream length, fair in 30%, and good in 45%.
- Riparian vegetative cover is in poor condition in 18% of river and stream length, fair in 13%, and good in 69%.
- Riparian disturbance is rated poor in 13% of river and stream length, fair in 40%, and good in 47%.

Upper Midwest

Setting

The Upper Midwest ecoregion covers most of Minnesota's northern half and southeastern area, two-thirds of Wisconsin and almost all of Michigan, extending about 160,374 square miles, or 5% of the conterminous United States. National and state forests and federal lands account for approximately 25,000 square miles, or 16%, of the ecoregion. The river systems in this ecoregion empty into portions of the Great Lakes regional watershed and the upper Mississippi River watershed. Major river systems include the upper Mississippi River in Minnesota and Wisconsin; the Wisconsin, Chippewa and St. Croix rivers in Wisconsin; and the Menominee and Escanaba rivers in Michigan. Other important water bodies include Lakes Superior, Michigan, Huron and Erie.

Virtually all of the virgin forest in this ecoregion was cleared in the 19th and early 20th centuries, and rivers and streams were greatly affected by logging. The Great Lakes aquatic systems are subject to increasing impact from invasive animal and plant species, including the zebra mussel, round goby, river ruffe, spiny water flea and Eurasian watermilfoil. Major manufacturing and chemical, steel, and power production occur in the large metropolitan areas of the Upper Midwest ecoregion.

Streams in the Upper Midwest ecoregion typically drain relatively small catchments and empty directly into the Great Lakes or Upper Mississippi River. These streams generally have steep gradients, but their topography and soils tend to slow runoff and sustain flow throughout the year. The total river and stream length represented in the NRSA for the Upper Midwest ecoregion is 92,554 miles.

The glaciated terrain of this ecoregion typically consists of plains with some hills. Lakes, rivers and wetlands predominate in most areas. The climate is characterized by cold winters and relatively short summers, with mean annual temperatures ranging from 34°F to 54°F and annual precipitation ranging from 20 to 47 inches. Based on satellite images in the 2006 National Land Cover Dataset, the distribution of land cover in this ecoregion is 36% forested, 27% cultivated and 20% wetlands, with the remainder in various other types of land cover.

Summary of NRSA findings, Upper Midwest

A total of 157 NRSA sites were sampled to characterize the condition of rivers and streams in the Upper Midwest ecoregion. An overview of the findings is shown in **Figure 41**.

Biological condition

The macroinvertebrate MMI shows that 34% of river and stream length in the Upper Midwest ecoregion is in poor condition compared to least-disturbed conditions, 29% is in fair condition, and 37% is in good condition. The macroinvertebrate O/E taxa loss results show that 5% of river and stream length has lost more than 50% of the taxa expected to occur, and 13% of river and stream length has lost between 20% and 50% of expected taxa.

The fish MMI shows that 46% of river and stream length is in poor condition.

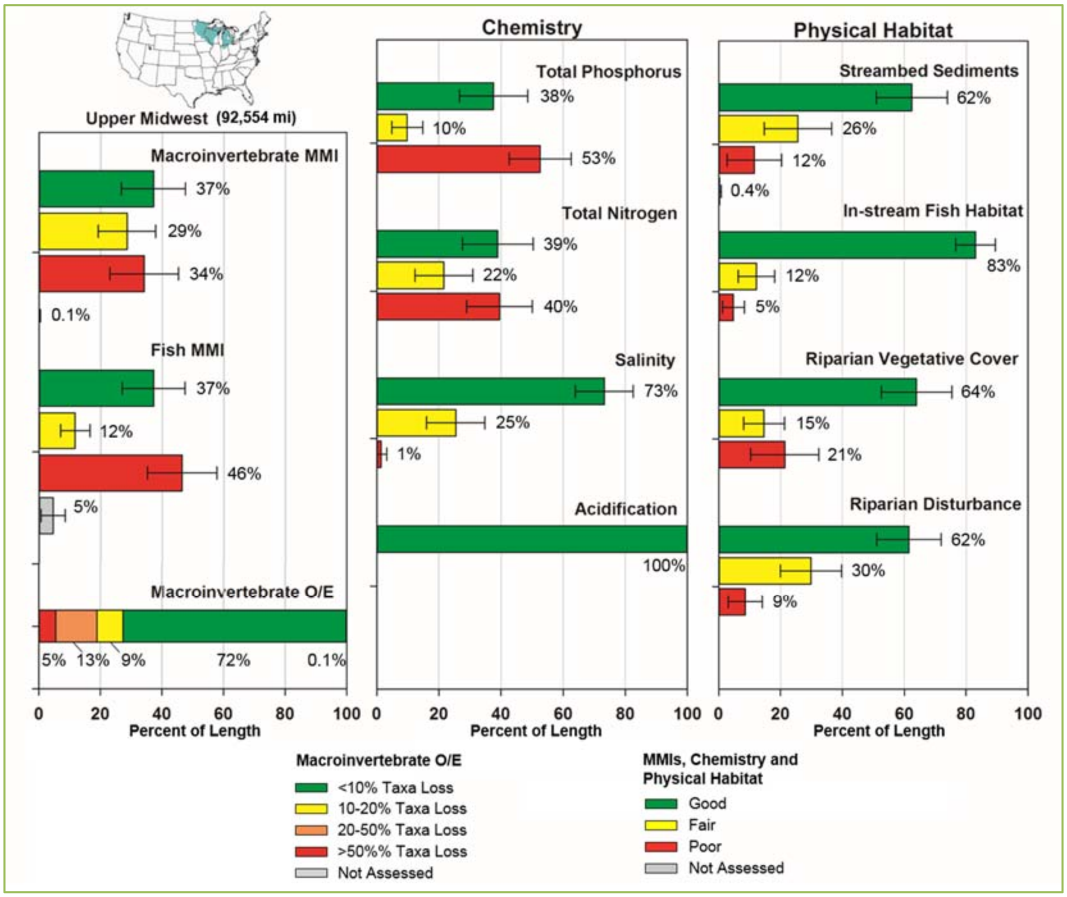


Figure 41. NRSA survey results for the Upper Midwest ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Upper Midwest ecoregion are phosphorus, nitrogen, riparian vegetative cover, streambed sediments and riparian disturbance. Compared to least-disturbed conditions for this ecoregion:

- Phosphorus is at high levels (rated poor) in 53% of river and stream length, medium levels (rated fair) in 10%, and low levels (rated good) in 38%.
- Nitrogen is at high levels (rated poor) in 40% of river and stream length, medium levels (rated fair) in 22%, and low levels (rated good) in 39%.
- Riparian vegetative cover is rated in poor condition in 21% of stream length, fair in 15%, and good in 64%.

- Streambed sediments is rated poor in 12% of river and stream length, fair in 26%, and good in 62%.
- Riparian disturbance is rated poor in 9% of river and stream length, fair in 30%, and good in 62%.

Temperate Plains

Setting

The Temperate Plains ecoregion includes Iowa; the eastern Dakotas; western Minnesota; portions of Missouri, Kansas and Nebraska; and the flat lands of western Ohio, central Indiana, Illinois and southeastern Wisconsin. This ecoregion covers about 342,200 square miles, or 11%, of the conterminous United States, with approximately 7,900 square miles under federal ownership. Many of the rivers in this ecoregion drain into the Upper Mississippi River, Ohio River and Great Lakes watersheds.

Much of this ecoregion is now primarily cultivated land, including field crop production (e.g., corn, wheat and alfalfa) and hog and cattle production. Crops and grazing have reduced natural riparian vegetative cover, increased sediment yield, and introduced pesticides and herbicides. Rivers have many species of fish, including minnows, darters, killifishes, catfishes, suckers, sunfishes and black bass.

Rivers and streams in the tall grass prairie start from prairie potholes and springs, and they may be ephemeral (flowing for a short time after snowmelt or rainfall). Rivers carry large volumes of fine sediments and tend to be turbid, wide and shallow. The total river and stream length represented in the NRSA for the Temperate Plains ecoregion is 230,725 miles.

The terrain of this ecoregion consists of smooth plains and many small lakes and wetlands. The climate is temperate, with cold winters, hot and humid summers and mean temperatures ranging from 36°F to 55°F. Annual precipitation ranges from 16 to 43 inches. Based on satellite images in the 2006 National Land Cover Dataset, the distribution of land cover in this ecoregion is 69% cultivated, 10% forested and 9% developed, with the remainder in other types of land cover.

Summary of NRSA findings, Temperate Plains

A total of 199 NRSA sites were sampled to characterize the condition of rivers and streams in the Temperate Plains ecoregion. An overview of the findings is shown in **Figure 42**.

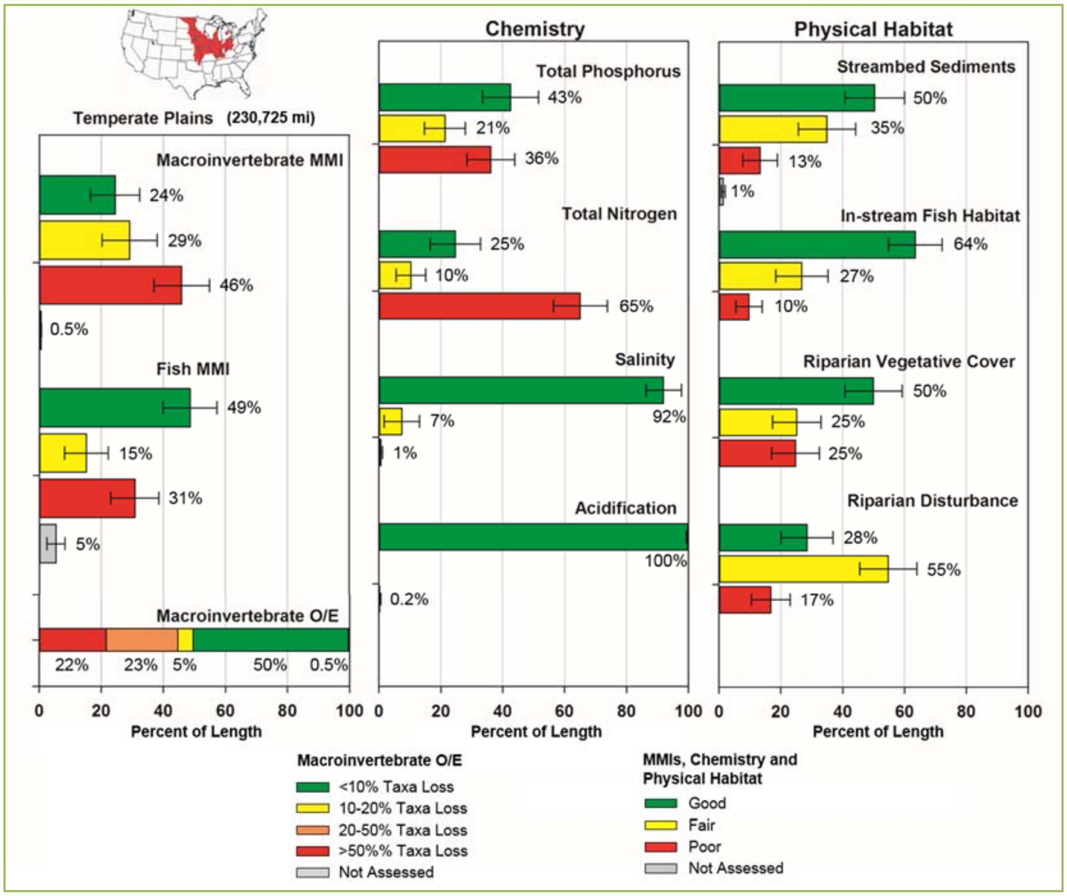


Figure 42. NRSA survey results for the Temperate Plains ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

Biological condition

The macroinvertebrate MMI shows that 46% of river and stream length in the Temperate Plains ecoregion is in poor condition compared to least-disturbed conditions, 29% is in fair condition, and 24% is in good condition. The macroinvertebrate O/E taxa loss results show that 22% of river and stream length has lost more than 50% of the taxa expected to occur, and 23% of river and stream length has lost between 20% and 50% of expected taxa.

The fish MMI shows that 31% of river and stream length is in poor condition.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Temperate Plains ecoregion are nitrogen, phosphorus, riparian vegetative cover, riparian disturbance and streambed sediments. Compared to least-disturbed conditions for this ecoregion:

- Nitrogen is at high levels (rated poor) in 65% of river and stream length, medium levels (rated fair) in 10%, and low levels (rated good) in 25%.
- Phosphorus is at high levels (rated poor) in 36% of river and stream length, medium levels (rated fair) in 21%, and low levels (rated good) in 43%.
- Riparian vegetative cover is rated as poor in 25% of river and stream length, fair in 25%, and good in 50%.
- Riparian disturbance is at high levels (rated poor) in 17% of river and stream length, medium levels (rated fair) in 55%, and low levels (rated good) in 28%.
- Streambed sediments are rated poor in 13% of river and stream length, fair in 35%, and good in 50%.

Southern Plains

Setting

The Southern Plains ecoregion covers about 405,000 square miles (14% of the conterminous United States) and includes central and northern Texas; most of western Kansas and Oklahoma; and portions of Nebraska, Colorado and New Mexico. The Arkansas, Platte, White, Red and Rio Grande rivers flow through this ecoregion, and most of the Ogallala aquifer (one of the world's largest water table aquifers, which supplies irrigation and drinking water to eight states) lies underneath it. Federal land ownership in this ecoregion totals about 11,980 square miles, or about 3% of the total.

The terrain is a mix of smooth and irregular plains interspersed with tablelands and low hills. The Great Prairie grasslands, which once covered much of the Southern Plains ecoregion, are the most altered and endangered large ecosystem in the United States. About 90% of the original tall grass prairie was replaced by other vegetation; agriculture and livestock grazing and production are prevalent. Agriculture is an important economic activity in this ecoregion, and it includes sorghum, wheat, corn, sunflower, bean and cotton production. Livestock production and processing is also prevalent. This ecoregion also contains a sizable portion of U.S. petroleum and natural gas production in

Oklahoma, Kansas and Texas. The total river and stream length represented in the NRSA for the Southern Plains ecoregion is 36,570 miles.

Based on satellite images in the 2006 National Land Cover Dataset, the land in this ecoregion is 62% grassland/shrub, 27% cultivated and 5% forested, with the remainder in other types of land cover. The climate in this ecoregion is dry temperate, with mean annual temperatures ranging from 45° to 79°F. Annual precipitation is between 10 and 30 inches.

Summary of NRSA findings, Southern Plains

A total of 165 NRSA sites were sampled to characterize the condition of rivers and streams in the Southern Plains ecoregion. An overview of the findings is shown in **Figure 43**.

Biological condition

The macroinvertebrate MMI shows that 27% of river and stream length in the Southern Plains ecoregion is in poor condition compared to least-disturbed conditions, 25% is in fair condition, and 46% is in good condition. The macroinvertebrate O/E taxa loss results show that 23% of river and stream length has lost more than 50% of the taxa expected to occur, and 28% of river and stream length has lost between 20% and 50% of expected taxa.

The fish MMI shows that 25% of river and stream length is in poor condition. Twenty percent of river and stream length is not assessed or, for various reasons, has insufficient data to calculate the fish MMI.

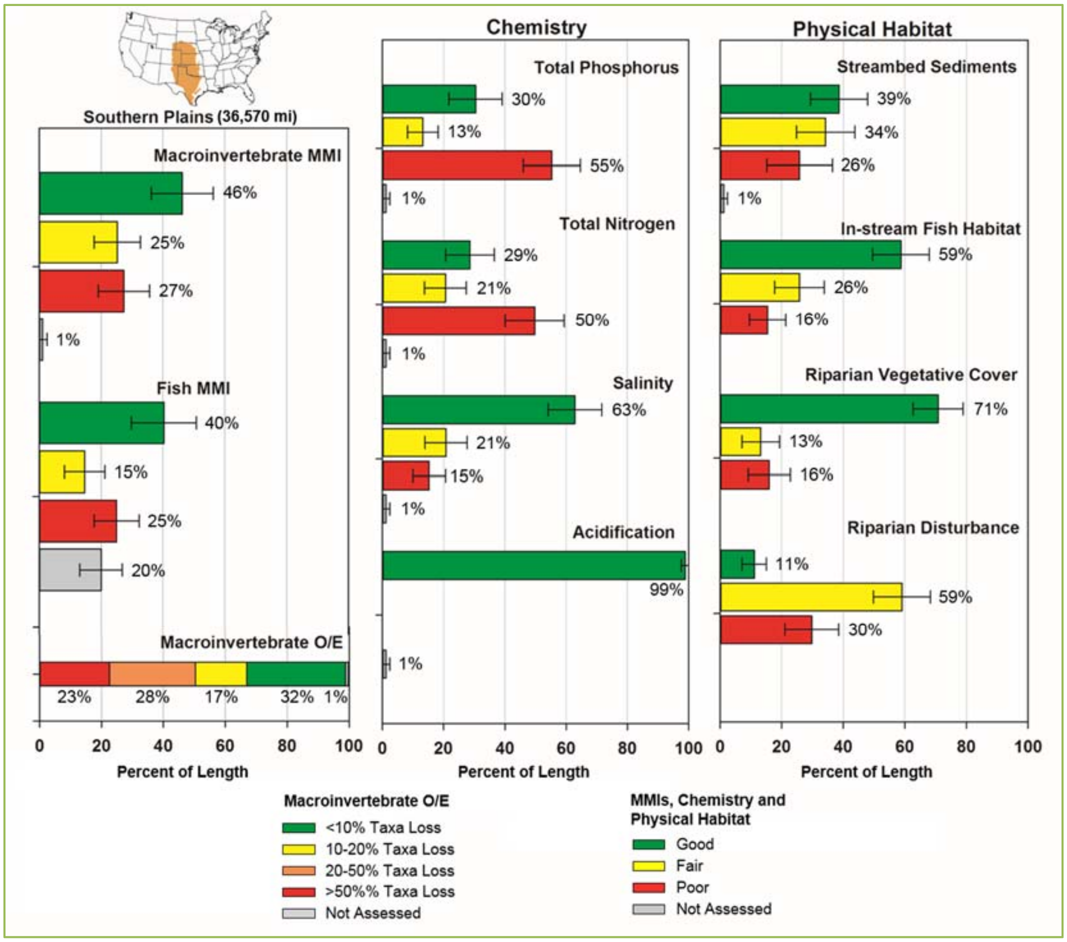


Figure 43. NRSA survey results for the Southern Plains ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Southern Plains ecoregion are phosphorus, nitrogen, riparian disturbance, streambed sediments, riparian vegetative cover, and in-stream fish habitat. Compared to least-disturbed conditions for this ecoregion:

- Phosphorus is at high levels (rated poor) in 55% of river and stream length, medium levels (rated fair) in 13%, and low levels (rated good) in 30%.
- Nitrogen is at high levels (rated poor) in 50% of river and stream length, medium levels (rated fair) in 21%, and low levels (rated good) in 29%.

- Riparian disturbance is at high levels (rated poor) in 30% of river and stream length, medium levels (rated fair) in 59%, and low levels (rated good) in only 11%.

- Streambed sediments are rated poor in 26% of river and stream length, fair in 34%, and good in 39%.

- Riparian vegetative cover and in-stream fish habitat are both rated poor in 16% of river and stream length.

Northern Plains

Setting

The Northern Plains ecoregion covers approximately 205,084 square miles, or 7% of the conterminous United States. It includes the western Dakotas, Montana east of the Rocky Mountains, northeast Wyoming and a small section of northern Nebraska. This ecoregion is the heart of the Missouri River system and is almost exclusively within the Missouri River's watershed. Federal lands account for 52,660 square miles, or nearly 26% of the total area.

Human economic activity in this ecoregion is primarily agriculture, including cropland and cattle and sheep grazing. Coal mining occurs in the portions of North Dakota, Montana and Wyoming that are within the ecoregion, and petroleum and natural gas production are growing.

This ecoregion's terrain is irregular plains interspersed with tablelands and low hills. The Great Prairie grasslands were once an important feature of this ecoregion, but they have largely been replaced by other vegetation or land uses, particularly cropland. The total river and stream length represented in the NRSA for the Northern Plains ecoregion is 26,987 miles.

Based on satellite images in the 2006 National Land Cover Dataset, the land in this ecoregion is 68% grassland/shrub, 23% cultivated and 3% forested, with the remainder in other types of land cover. The climate in this ecoregion is dry and characterized by short, hot summers and long, cold winters. Temperatures average 36°F to 46°F, and annual precipitation totals range from 10 to 25 inches. High winds are an important climatic factor in this ecoregion, which is also subject to periodic intense droughts and frosts.

Summary of NRSA findings, Northern Plains

A total of 174 NRSA sites were sampled to characterize the condition of rivers and streams in the Northern Plains ecoregion. An overview of the findings is shown in **Figure 44**.

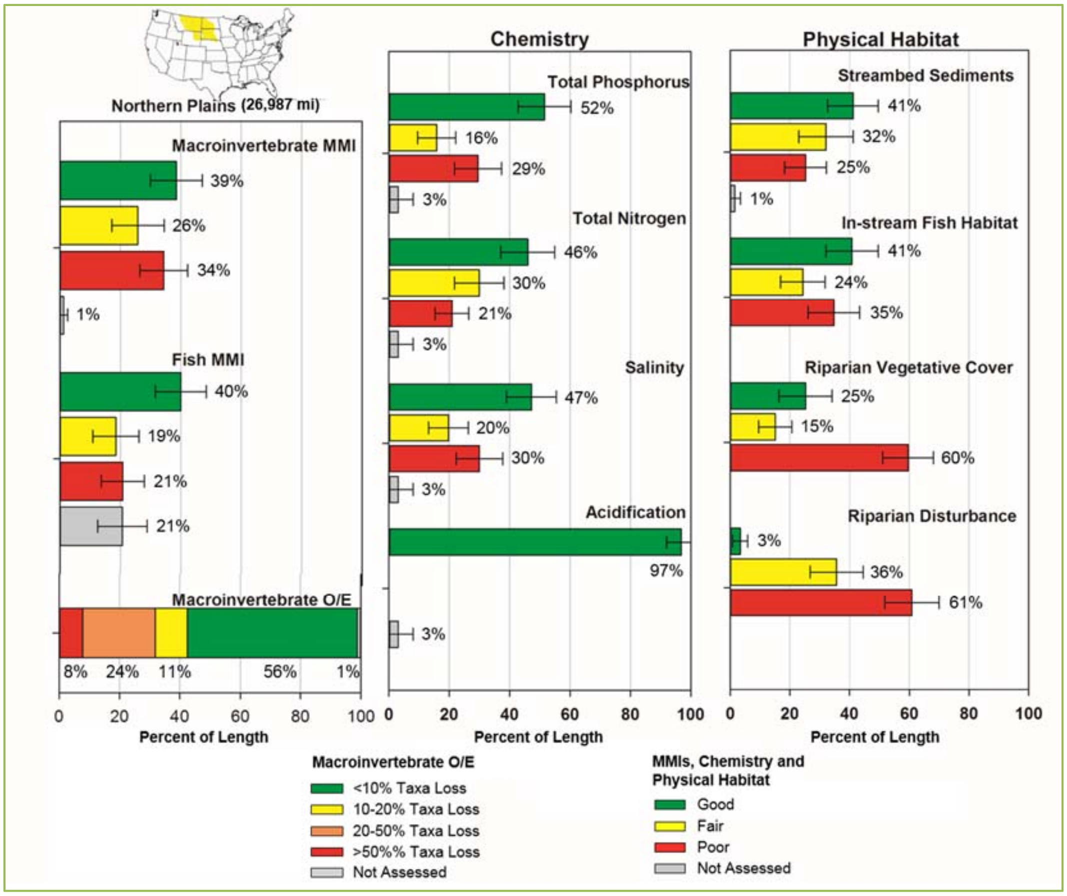


Figure 44. NRSA survey results for the Northern Plains ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

Biological condition

The macroinvertebrate MMI shows that 34% of river and stream length in the Northern Plains ecoregion is in poor condition compared to least-disturbed conditions, 26% is in fair condition, and 39% is in good condition. The macroinvertebrate O/E taxa loss results show that 8% of river and stream length has lost more than 50% of the taxa expected to occur, and 24% of river and stream length has lost between 20% and 50% of expected taxa.

The fish MMI shows that 21% of river and stream length is in poor condition. Twenty-one percent of river and stream length is not assessed or, for various reasons, has insufficient data to calculate the fish MMI.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Northern Plains ecoregion are riparian disturbance, riparian vegetative cover, in-stream fish habitat, salinity and phosphorus. Compared to least-disturbed conditions for this ecoregion:

- Riparian disturbance is rated poor in 61% of river and stream length, fair in 36%, and good in 3%.
- Riparian vegetative cover is rated poor in 60% of river and stream length, fair in 15%, and good in 25%.
- In-stream fish habitat is rated poor in 35% of river and stream length, fair in 24%, and good in 41%.
- Salinity is a widespread stressor in the Northern Plains, although not in most ecoregions. It is found at high levels (rated poor) in 30% of river and stream length, at medium levels (rated fair) in 20%, and at low levels (rated good) in 47%.
- Phosphorus is at high levels (rated poor) in 29% of river and stream length, medium levels (rated fair) in 16%, and low levels (rated good) in 52%.

Western Mountains

Setting

The Western Mountains ecoregion includes the Cascade, Sierra Nevada, and Pacific Coast ranges in the coastal states; the Gila Mountains in the southwestern states; and the Bitterroot and Rocky mountain ranges in the northern and central mountain states. The headwaters and upper reaches of the Columbia, Sacramento, Missouri and Colorado river systems all occur in this ecoregion. This ecoregion covers about 397,832 square miles, with about 297,900 square miles, or 75% of the land, classified as federal land.

The terrain of the Western Mountains ecoregion is characterized by extensive mountains and plateaus separated by wide valleys and lowlands. Coastal mountains are transected by many fjords and glacial valleys, are bordered by coastal plains and include important estuaries along the margins of the ocean. Soils are mainly nutrient-poor forest soils. Rivers drain dense forested catchments and contain much woody debris that provides habitat diversity and stability. Rivers reaching the Pacific Ocean historically had large runs of salmon and trout; however, many of these populations have been reduced by the effects of dams, flow regulation, overfishing and invasive species. Smaller rivers generally start as steep mountain streams with staircase-like channels, steps, and plunge pools, with riffles and pools appearing as the slope decreases. Upper river reaches experience debris flows and landslides when shallow soils become saturated by rainfall or snowmelt. The total river and stream length represented in the NRSA for the Western Mountains ecoregion is 151,269 miles.

Based on satellite images in the 2006 National Land Cover Dataset, the land in this ecoregion is 55% forested and 36% shrub/scrub and grassland, with the remainder in other types of land cover. The climate is sub-arid to arid and mild in southern lower valleys; it is humid and cold at higher elevations. The wettest climates of North America occur in the marine coastal rainforests of this ecoregion. Mean annual temperatures range from 32°F to 55°F, and annual precipitation ranges from 16 to 240 inches.

Summary of NRSA findings, Western Mountains

A total of 209 NRSA sites were sampled to characterize the condition of rivers and streams in the Western Mountains ecoregion. An overview of the findings is shown in **Figure 45**.

Biological condition

The macroinvertebrate MMI shows that 22% of river and stream length in the Western Mountains ecoregion is in poor condition compared to least-disturbed conditions, 27% is in fair condition, and 50% is in good condition. The macroinvertebrate O/E taxa loss results show that 6% of river and stream length has lost more than 50% of the taxa expected to occur, and 18% of river and stream length has lost between 20% and 50% of expected taxa.

The fish MMI shows that 23% of river and stream length is in poor condition. Twenty-three percent of river and stream length is not assessed or, for various reasons, has insufficient data to calculate the fish MMI.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Western Mountains ecoregion are phosphorus, riparian disturbance, nitrogen, riparian vegetative cover and streambed sediments. Compared to least-disturbed conditions for this ecoregion:

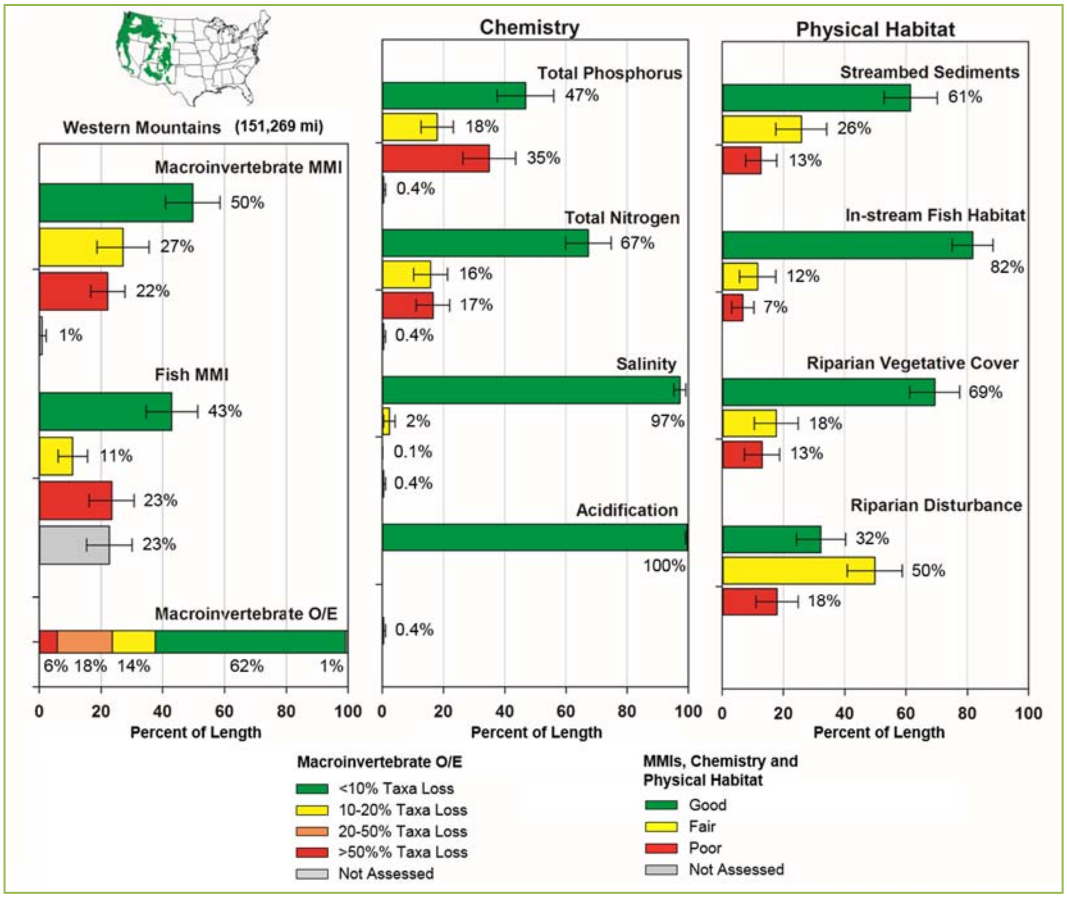


Figure 45. NRSA survey results for the Western Mountains ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

- Phosphorus is at high levels (rated poor) in 35% of river and stream length, medium levels (rated fair) in 18%, and low levels (rated good) in 47%.
- Riparian disturbance is rated poor in 18% of river and stream length, fair in 50%, and good in 32%.
- Nitrogen is at high levels (rated poor) in 17% of river and stream length, medium levels (rated fair) in 16%, and low levels (rated good) in 67%.
- Riparian vegetative cover is rated poor in 13% of river and stream length, fair in 18%, and good in 69%.
- Similarly, streambed sediments are rated poor in 13% of river and stream length, fair in 26%, and good in 61%.

Xeric

Setting

The Xeric ecoregion covers the largest area of all NRSA aggregate ecoregions and includes the most total land under federal ownership. It covers portions of 11 western states and all of Nevada, for a total of approximately 636,583 square miles, or 21% of the conterminous United States. Approximately 453,000 square miles, or 71% of the land, are classified as federal lands, including the Grand Canyon National Park, Big Bend National Park and Hanford Nuclear Reservation.

The terrain of the Xeric ecoregion is composed of a mix of physiographic features, including plains with hills and low mountains, high-relief tablelands, piedmont, high mountains and intermountain basins and valleys. The ecoregion includes the flat to rolling topography of the Columbia/Snake River Plateau; the Great Basin; Death Valley; and the canyons, cliffs, buttes and mesas of the Colorado Plateau. Its relatively limited surface water supply contributes to the Upper and Lower Colorado, Great Basin, California, Rio Grande, and Pacific Northwest regional watersheds. Large rivers flow all year, are supplied by snowmelt, and peak in early summer. Small rivers are mostly ephemeral. Rivers are often subject to rapid change due to flash floods and debris flows. In southern areas of the ecoregion, internal drainages often end in saline lakes or desert basins without reaching the ocean (e.g., Utah's Great Salt Lake).

Rivers in this ecoregion create a riparian habitat oasis for plants and animals. Many fish are endemic and have evolved to cope with warm, turbid waters. Many are threatened or endangered due to flow regulations from dams, water withdrawals and invasive species. The total river and stream length represented in the NRSA for the Xeric ecoregion is 44,943 miles.

Based on satellite images in the 2006 National Land Cover Dataset, the land in this ecoregion is 77% shrub/scrub and grassland, 8% cultivated and 7% forested, with the remainder in various types of land cover. The climate in this ecoregion varies widely from warm and dry to temperate, with mean annual temperatures ranging from 32°F to 75°F and annual precipitation ranging from 2 to 40 inches.

Summary of NRSA findings, Xeric

A total of 192 NRSA sites were sampled to characterize the condition of rivers and streams in the Xeric ecoregion. An overview of the findings is shown in **Figure 46**.

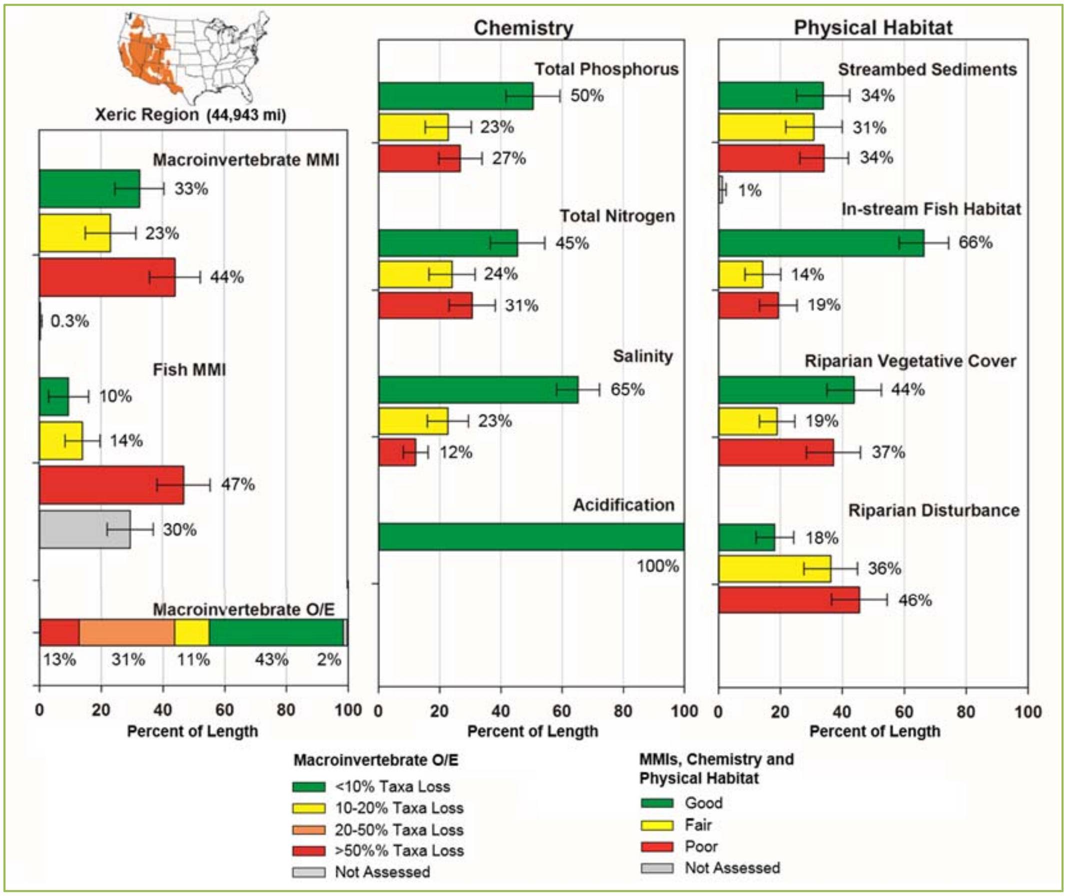


Figure 46. NRSA survey results for the Xeric ecoregion (EPA/NRSA). Bars show the percentage of river and stream length within a condition class for a given indicator. Percentages may not add up to 100% due to rounding.

Biological condition

The macroinvertebrate MMI shows that 44% of river and stream length in the Xeric ecoregion is in poor condition compared to least-disturbed conditions, 23% is in fair condition, and 33% is in good condition. The macroinvertebrate O/E taxa loss results show that 13% of river and stream length has lost more than 50% of the taxa expected to occur, and 31% of river and stream length has lost between 20% and 50% of expected taxa.

The fish MMI shows that 47% of river and stream length is in poor condition. Thirty percent of river and stream length is not assessed or, for various reasons, has insufficient data to calculate the fish MMI.

Indicators of stress

Of the indicators of stress measured for the NRSA, the most widespread in the Xeric ecoregion are riparian disturbance, riparian vegetative cover, streambed sediments, nitrogen and phosphorus. Compared to least-disturbed conditions for this ecoregion:

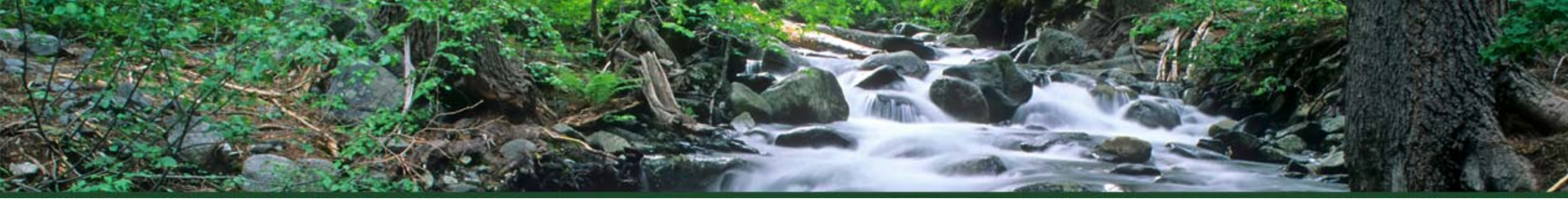
- Riparian disturbance is rated poor in 46% of river and stream length, fair in 36%, and good in 18%.

- Riparian vegetative cover is in poor condition in 37% of river and stream length, fair condition in 19%, and good condition in 44%.

- Streambed sediments are rated poor in 34% of river and stream length, fair in 31%, and good in 34%.

- Nitrogen is at high levels (rated poor) in 31% of river and stream length, medium levels (rated fair) in 24%, and low levels (rated good) in 45%.

- Phosphorus is at high levels (rated poor) in 27% of river and stream length, medium levels (rated fair) in 23%, and low levels (rated good) in 50%.



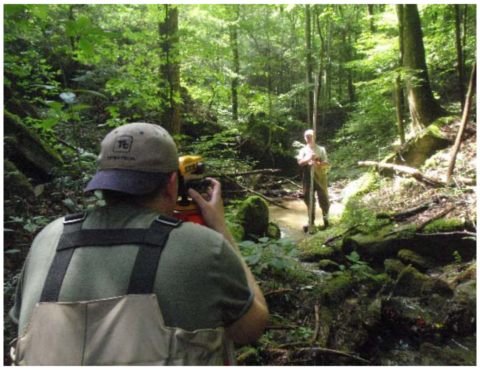
Chapter 7. Summary and Next Steps

This first NRSA was an unprecedented sampling and analytical effort by EPA and its state and tribal partners. Over two summers, 85 field crews sampled nearly 2,000 sites along the nation's wide-ranging rivers and streams. Twenty-two separate field training sessions were held to prepare for this survey. The efforts of the field crews yielded over 25,000 samples shipped to laboratories across the country. For example, over the course of the survey, 3,300 benthic macroinvertebrate samples (each sample with hundreds of individual preserved macroinvertebrates) were shipped to eight laboratories for sorting, identification and analysis. Seventeen different indicators were sampled or evaluated at the NRSA sites. Ten million bits of data were collected in field and analyzed in laboratories. These data from the NRSA are available at http://www.epa.gov/national-aquatic-resource-surveys.

Overall, the NRSA finds that biological communities in our rivers and streams are being heavily affected and degraded across the country. Nearly half of the nation's river and stream length is in poor condition based on a commonly used index that combines different measures of the condition of aquatic benthic macroinvertebrates. The eastern and mid-western ecoregions have the most waters in poor biological condition for macroinvertebrates, with the percentage of rivers and streams rated poor ranging from 34% to 69%. In the western ecoregions (including the Northern and Southern Plains ecoregions), the percentage of rivers and streams in poor biological condition ranges from 22% to 44%. Nationally, biological indices based on fish communities show similar results, with 36% of river and stream miles in poor condition for fish.

Of the four chemical stressors assessed, excessive phosphorus and nitrogen levels are the most widespread. Biological communities are almost twice as likely to be in poor condition when phosphorus and nitrogen levels are high. Phosphorus is the most widespread stressor in six of the nine ecoregions, and nitrogen is the most widespread in one ecoregion. Analysis of the NRSA data suggests that if phosphorus levels were reduced in areas where levels are currently high, we might see 30% of the nation's river and stream length that is in poor biological condition improve to good or fair conditions, a recovery of 170,000 miles (14%).

Of the four physical habitat stressors assessed in the NRSA, poor riparian vegetative cover and high levels of riparian disturbance are the most widespread, occurring in 24% and 20% of the nation's river and stream length respectively. Riparian disturbance is the most widespread stressor in two of the nine ecoregions. However, excess streambed sediments, which can be influenced by riparian conditions, have a somewhat greater impact on biological condition. Poor biological condition is about twice as likely in rivers and streams with excessive levels of streambed sediments. Thirteen percent of the river and stream length that is in poor biological condition might improve to good or fair conditions for macroinvertebrates if excess levels of streambed sediments were reduced or eliminated.



Crew members take slope and sinuosity readings in a wadeable stream. (Photo courtesy of Tetra Tech, Inc.)

The NRSA also includes two indicators that provide insight into potential risks to human health. It finds that in 23% of the nation's river and stream length, levels of enterococci bacteria exceed threshold levels for protecting human health. Additionally, the NRSA reports that over 13,000 miles of rivers have mercury levels in fish tissue that exceed human health screening values.

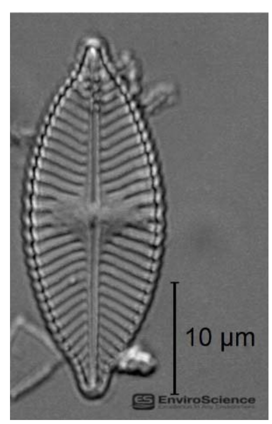
As we continue to implement these surveys over time, an important element of the NRSA is the ability to track changes in the condition of our rivers and streams. This report provides a first glimpse of that capability by examining the differences between stream conditions as reported in 2004 and wadeable systems assessed as part of the NRSA. Several NRSA indicators show statistically significant change compared to the 2004 WSA. An increase in stream length in good condition is evident for riparian disturbance and riparian vegetation; however, there is also a decrease in stream length in good condition for phosphorus and overall biological condition as measured by the macroinvertebrate index. These findings of change apply only to streams and are only identifying differences between two points in time; they should not be interpreted as trends in water quality conditions. Reasons for the changes have not been determined, although work continues in evaluating possible human or natural explanations. Future assessments of the nation's rivers and streams will be able to provide more robust trend assessments as additional years of data become available and as our understanding of the relationship between human activity, natural phenomena and environmental change mature.

The survey's findings that nearly half of river and stream length is in poor biological condition and that excess nutrients, sediment and poor habitat are widespread contributors to poor condition support continued management attention to these problems at the national, regional, state and watershed scales. Management actions should focus not only on improving those areas where biological conditions are poor, nutrient levels are high, and habitat conditions are already degraded, but on protecting those areas that are still in good condition. We have made great progress as a nation in improving water quality since the passage of the CWA; now, at a time when environmental agencies at all levels face increasing resource limitations, it will be challenging to maintain the progress we have made and sharpen our focus on remaining problems.

Moving the science forward

Many contributions of the NRSA go beyond the findings discussed in this report. Scientists developed new methods of sampling and assessing important water indicators such as streambed sediments; data were collected on leading-edge indicators that will be analyzed and reported separately; and state and tribal partners gained and shared expertise in state-of-the-art field monitoring methods and probability-based surveys.

One example of ongoing research involves the development of a periphyton (algae) multi-metric index at the national and ecoregional scales. Periphyton—bottom-dwelling algae that attach themselves to stream and river beds, plants, rocks and woody debris—are an important foundation of many river and stream food webs. They stabilize substrates and serve as habitat for many other organisms. Because they are attached, they are affected by physical, chemical and biological disturbances in the water body.



Diatom: Planothidium apiculatum. (Photo courtesy of Melissa Vaccarino, EnviroScience, Inc.

Diatoms are some of the most common species of periphyton. Diatoms are considered to be useful biological indicators because they are found in abundance in most river and stream ecosystems. They grow as single cells but can also form filaments or colonies. The great numbers of diatom species in rivers and streams provide multiple sensitive indicators of environmental change and the specific conditions of their habitat. Unique among algae, diatoms have cell walls composed of silica (glass), which are intricate and beautiful.

Several state programs have developed or are developing indicators based on periphyton (e.g., Maine and New Jersey). The EMAP program showed promising results in development of a regional-scale periphyton indicator in the western United States. However, few large-scale national assessments using this indicator have occurred, especially for the Plains and Lowlands region of the United States. EPA and partners conducted research as part of the NRSA to further evaluate this indicator for national-scale assessments.

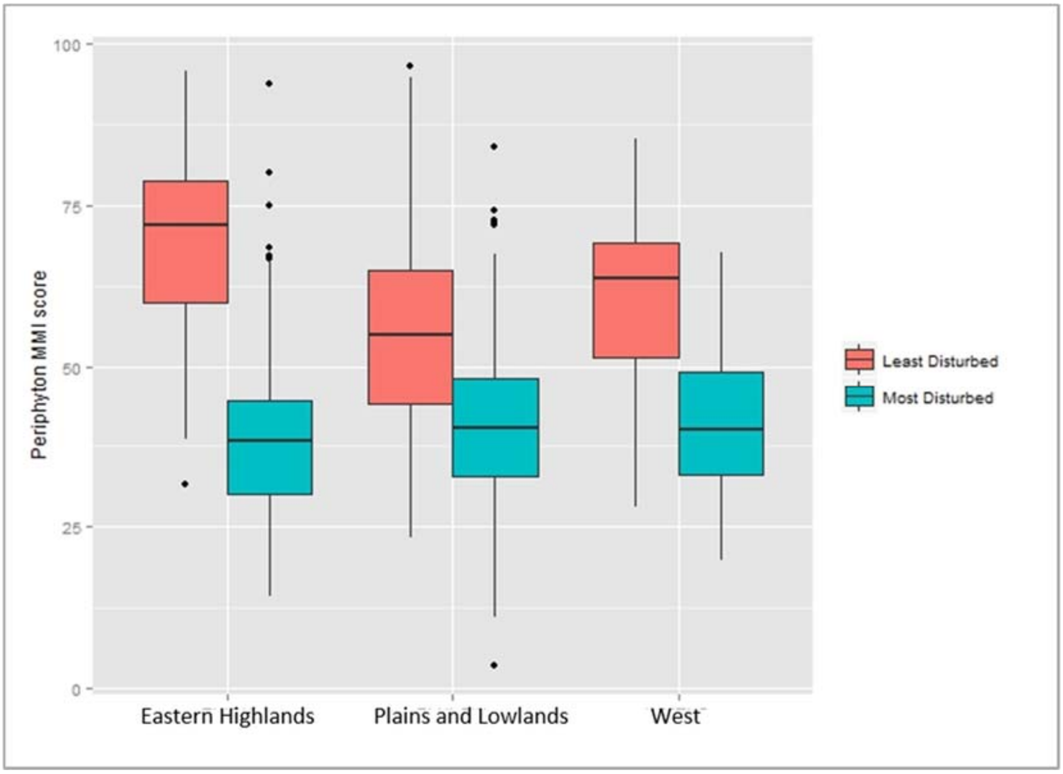


Figure 47. Distribution of periphyton MMI score for both least- and most-disturbed sites from each of the three large aggregate regions: Eastern Highlands, Plains and Lowlands, and West (EPA/NRSA).

In testing this indicator for the NRSA, crews collected algae samples at all NRSA sites across the country. A number of scientists then identified diatom algae species. To develop an index based on diatoms, the initial NRSA analysis was completed for the three climatic regions using an approach similar to the construction of the macroinvertebrate MMI. The draft MMI performed well in the Eastern Highlands and West, but did not discriminate as effectively between least-disturbed and most-disturbed conditions in the Plains and Lowlands, suggesting that more work is needed to apply this indicator nationally (Figure 47).

EPA and its partners are working to address several key areas of research related to the periphyton indicator, including taxonomic consistency and the discrimination issue discussed above. For example, EPA is working with USGS and other partners to develop helpful resources for identifying the most common taxa and exploring DNA methods for taxonomic identification. Related to discrimination, analysts are considering whether alternative approaches for establishing thresholds might be more effective for this particular aquatic assemblage.

In other areas of research, NRSA scientists are working to develop assessment and reporting methods that will more fully integrate biological indicators into one assessment to evaluate the overall condition of rivers and streams. Transferring NRSA methods and technology to state and tribal programs is another key aspect of moving the science forward.

EPA included several leading-edge indicators as part of the NRSA to address emerging issues and developments in aquatic sciences and to support innovative research within EPA. For example, the EPA Office of Research and Development led an effort to study microbial sediment enzyme activity (or sediment enzymes), an indicator that focuses on nutrient concentration within the streambed sediment. The work to collect and analyze sediment enzymes is helping EPA and its partners better understand nutrient limiting factors within the stream or river channel that affect the biological community. The result may prove to be a sensitive indicator that can help us implement the most effective management action to address nutrient pollution. A number of peer-reviewed journal articles focus on the technical aspects of the analysis and assessment of this innovative indicator.

Next steps

As this report was being written and revised, EPA and its state and tribal partners took stock of the lessons learned from the 2008–2009 survey as well as from other National Aquatic Resource Surveys. In 2013 and 2014, more than 2000 sites were sampled for the next NRSA report. EPA, states, tribes and federal partners expect to continue producing national water quality assessments for coastal waters, wetlands, lakes and rivers and streams on a regular cycle under the NARS program.

As these national assessments continue, many states are developing and conducting their own state-scale probability surveys of their rivers and streams, lakes and coastal waters (see California highlight, below). EPA will continue to explore ways to best support states as they sample, analyze and report on their waters using these surveys. For example, EPA is working to build and refine tools states can use to assess survey data at different scales and is exploring options for providing direct technical support. EPA will make available the statistical codes that were used to develop the MMIs and thresholds for assessment. EPA is also piloting training on the statistical tools and methods that were used in the National Lakes Assessment. Modifications and refinements will be made to this pilot effort to train states and tribes for the NRSA and other NARS programs.

This survey would not have been possible without the assistance and collaboration of hundreds of scientists working for universities and state, federal and tribal agencies across the country. These scientists helped plan and design the survey, select sites and indicators, develop and improve monitoring methods, train crew members, conduct sampling, track samples, screen and analyze results and review and write up the findings. Working together on future national surveys, and on state-scale surveys of similar design, EPA and its partners will continue developing a high-quality baseline of information on rivers and streams that can be used to evaluate progress toward protecting and restoring them.

California uses the NARS approach to enhance monitoring effectiveness

Introduction

One of the strengths of the NARS program has been its ability to transfer significant technical advances in monitoring approaches and techniques to states and tribes. Partnerships with states and tribes were designed to help build local capacity to take advantage of the new tools that the NARS program was developing.

Over the last 12 years, California has embraced this technical and partnership approach. After participating in the EPA EMAP Western pilot to monitor streams and rivers, California used what it had learned to produce a thriving program that is transforming the way water quality monitoring is conducted and data are evaluated throughout the state. Since 2000, California has leveraged approximately 250 EMAP/NRSA sites into a probability dataset of over 1,200 sites (**Figure 48**). The list of data applications and opportunities for partnerships keeps growing every year.

Figure 48. Map of approximately 1,200 probability sites in California sampled since 2000 using compatible EMAP-style survey designs.

California uses the NARS approach to enhance monitoring effectiveness (continued)

Regional assessments and land use assessments

The high density of sites in California supports the development of regional assessments and analyses (e.g., of stressor extent and risk) that are more relevant to the scale at which policy and management decisions are made (**Figure 49**). California also added the ability to produce summaries for major land cover classes such as forested, agricultural and urban (**Figure 50**). This was the first attempt to use a probability survey to produce land-use-specific assessments. Having knowledge of the probability-derived distribution of stressors and indicators in urban, agricultural and forested landscapes gives managers context for interpreting the results of monitoring done in these types of landscapes.

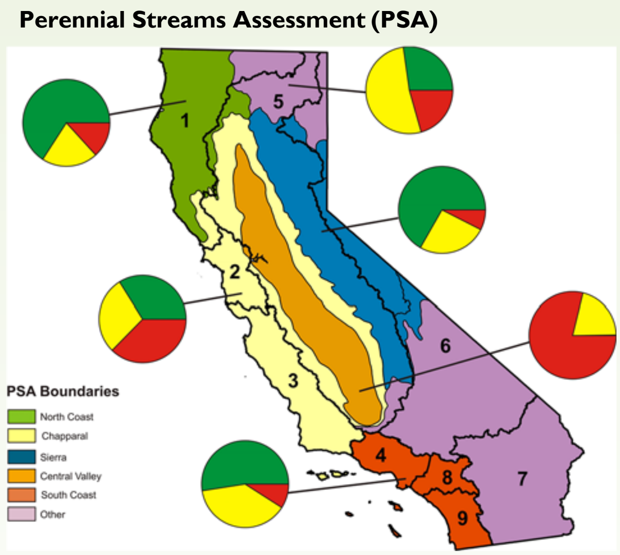


Figure 49. Biological condition of perennial streams in the six major ecoregions of California. Green = good biological condition, yellow = altered biological condition, and red = very altered biological condition.

Figure 50. Percentage of California stream length that exceeds severe (red) and moderate (yellow) threshold values for various chemical and physical habitat stressor variables in streams associated with each of three major land cover types.

California uses the NARS approach to enhance monitoring effectiveness (continued)

Exploring stressor–condition relationships

California measures a large suite of water chemistry and in-stream and riparian habitat parameters in addition to ecological condition indicators such as benthic macroinvertebrates and algae. Site-specific information is supplemented with over a hundred layers of GIS data that look across the site, watershed and region. This provides a dataset that can be used to explore stressor–condition relationships for a wide variety of objectives (**Figure 51**). The ability to produce objective descriptions of stressor extent and relationships between stressors and biological condition holds even greater potential to influence California's resource management programs. Better understanding of these relationships is leading to significant improvements in California's ability to prioritize limited resources and to have more meaningful discussions about issues of concern with the public and with other agencies (**Figure 52**).

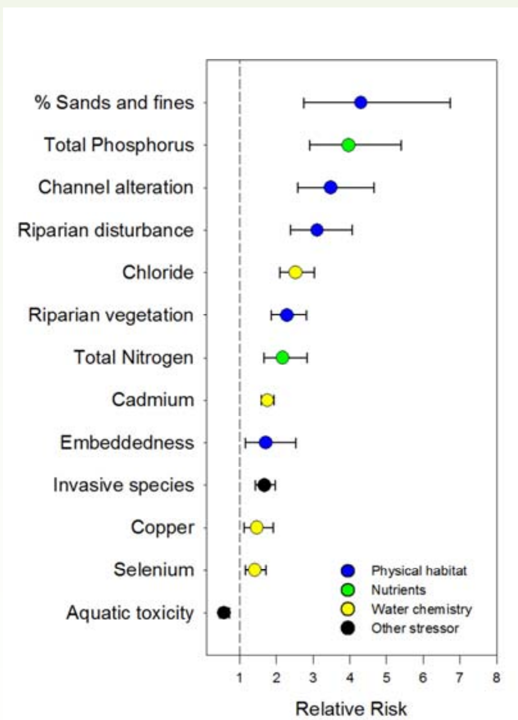


Figure 51. Relative risk of biological impairment associated with a series of habitat and chemistry variables in southern California streams.

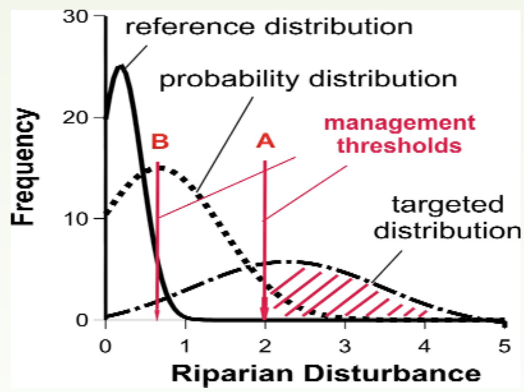


Figure 52. The combination of probability and reference distributions provides objective context for interpreting targeted monitoring data.

California uses the NARS approach to enhance monitoring effectiveness (continued)

Support for biocriteria development

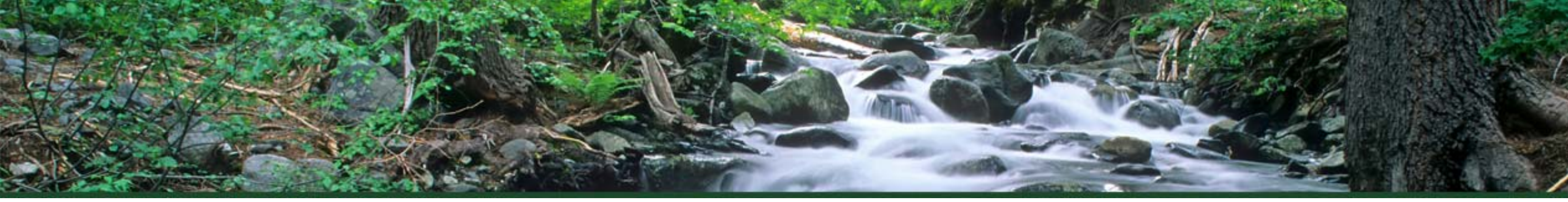
California's extensive probability datasets have given the state a solid foundation to move toward using ecological indicators for regulatory purposes, such as biocriteria development and refining reference condition. Probability data have also played an important role in the development of the technical elements of California's biocriteria policy, which is currently in progress.

Fostering inter-agency collaboration

California's statewide probability survey, the Perennial Streams Assessment, serves as a highly effective tool for encouraging collaboration among regional monitoring programs and federal agencies. For example, two successful monitoring partnerships in urban areas (southern coastal California and the San Francisco Bay Area) worked with the Assessment to create monitoring programs that were compatible with the Assessment's design and that allowed them to coordinate efforts and effectively use data across regional groups.

Partnerships with federal agencies have the potential for similar benefits in rural areas. Partnerships like those in California enable programs to do more with limited monitoring resources and provide feedback that improves the monitoring program. They help connect partners' management needs to the right data. California is using this approach to accelerate its progress toward the widespread use of ecological indicators in aquatic resource protection, including the development of multiple indicator assemblages (such as algae and wetland vegetative condition) and tools for a variety of aquatic resource types, including non-perennial streams, wetlands and large rivers.

For more information, visit the final report *Ecological Condition Assessments of California's Perennial Wadeable Streams* at www.waterboards.ca.gov/water_issues/programs/swamp/docs/reports/psa_smmry_rpt.pdf or contact Peter Ode, California Department of Fish and Wildlife, at Peter.Ode@wildlife.ca.gov.



List of Abbreviations and Acronyms

ANC	acid-neutralizing capacity
CPL	Coastal Plains
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
MMI	multi-metric index
NAP	Northern Appalachians
NARS	National Aquatic Resource Surveys
NHD	USGS National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NPL	Northern Plains
NRSA	National Rivers and Streams Assessment
O/E	observed/expected
PCB	polychlorinated biphenyl
qPCR	quantitative polymerase chain reaction
RBS	relative bed stability
SAP	Southern Appalachians
SPL	Southern Plains
TPL	Temperate Plains
UMW	Upper Midwest
USGS	U.S. Geological Survey
WMT	Western Mountains
WSA	Wadeable Streams Assessment
XER	Xeric region

Glossary of Terms

Benthic macroinvertebrates: Aquatic insects (such as dragonfly and beetle larvae), crustaceans (such as crayfish), worms and mollusks. These small creatures live throughout the stream bed attached to rocks, vegetation, logs and sticks or burrowed into stream bottoms.

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

Biological integrity: The state of being able to support and maintain a balanced community of organisms with a species composition, diversity and functional organization comparable to that of the natural habitat of the region.

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

In-stream fish habitat: Habitat features important to fish for concealment, feeding, and shelter from high water velocities and temperature; these features include large wood within the stream banks, boulders, undercut banks, and tree roots.

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

Macroinvertebrate Multi-metric Index (MMI): The sum of a number of individual measures of biological condition, such as the number of taxa in a sample, the number of taxa with different habits, and feeding strategies.

National Hydrography Dataset (NHD) Plus: A comprehensive set of digital spatial data—based on USGS 1:100,000 scale topographic maps—that contains information on surface water features such as streams, rivers, lakes and ponds.

Nutrients: Substances such as nitrogen and phosphorus that can over-stimulate the growth of algae and other plants in water. Nutrients in streams and lakes can come from agricultural and urban runoff, leaking septic systems, sewage discharges and similar sources.

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

Perennial streams: Streams that flow throughout the year.

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

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

Reach: A segment of stream length long enough to include a variety of habitat types (riffles, pools, bends, etc.) In NRSA, sample reaches are generally 40 times as long as they are wide.

Reference condition: The least-disturbed condition available in an ecoregion, determined based on specific criteria and used as a benchmark for comparison with sampled sites in the region.

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

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

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

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

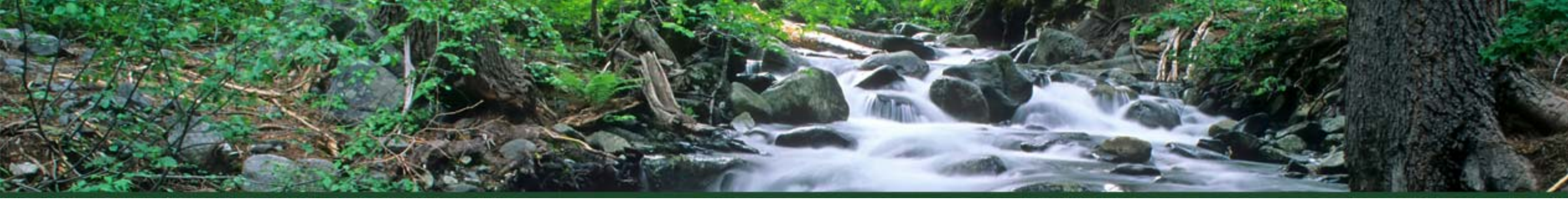
Stream order: Stream size, based on the confluence of one stream with another. First-order streams are the origin or headwaters. The confluence or joining of two first-order streams forms a second-order stream, the confluence of two second-order streams forms a third-order stream, and so on.

Stressors: Effects or substances that are stressful to—and therefore degrade—aquatic ecosystems. Stressors can be chemical (e.g., nutrients), physical (e.g., excess sediments on the streambed) or biological (e.g., competing invasive species).

Taxa: The plural of “taxon,” taxa are groupings of living organisms into categories (e.g., phylum, class, order, family, genus and species). Scientists group organisms into taxa in order to better identify and understand them.

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

Wadeable streams: Streams that are small and shallow enough to adequately sample by wading.



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