Acidification

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

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

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

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

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

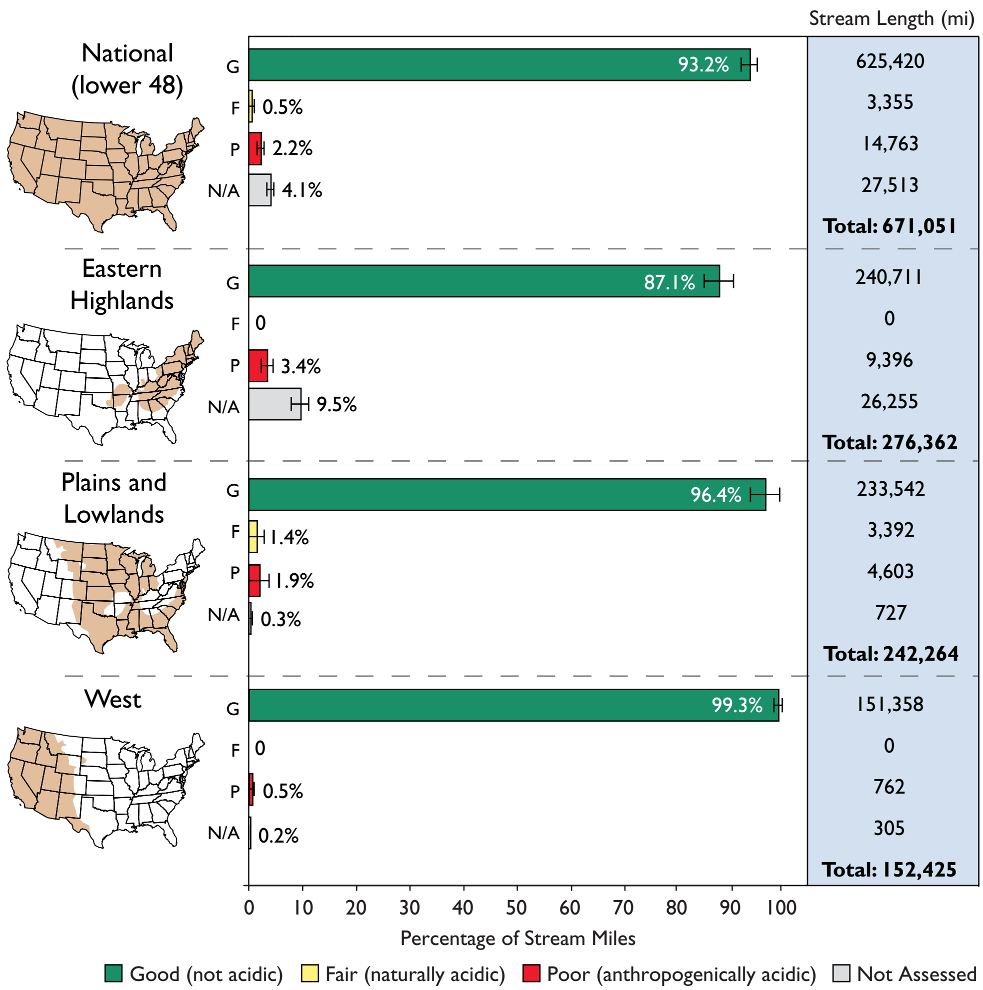


Figure 18. Acidification in U.S. streams (U.S. EPA/WSA). Streams are considered acidic when ANC values fall below zero. Streams are considered sensitive to acidification during rainfall events when ANC values are between 0 and 25 milliequilivents. Both ranges were scored as anthropogenically acidic in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

Findings for Acidification

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

Physical Habitat Stressors

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

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

Streambed Sediments

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

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

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

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

Findings for Streambed Sediments

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

In-stream Fish Habitat

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

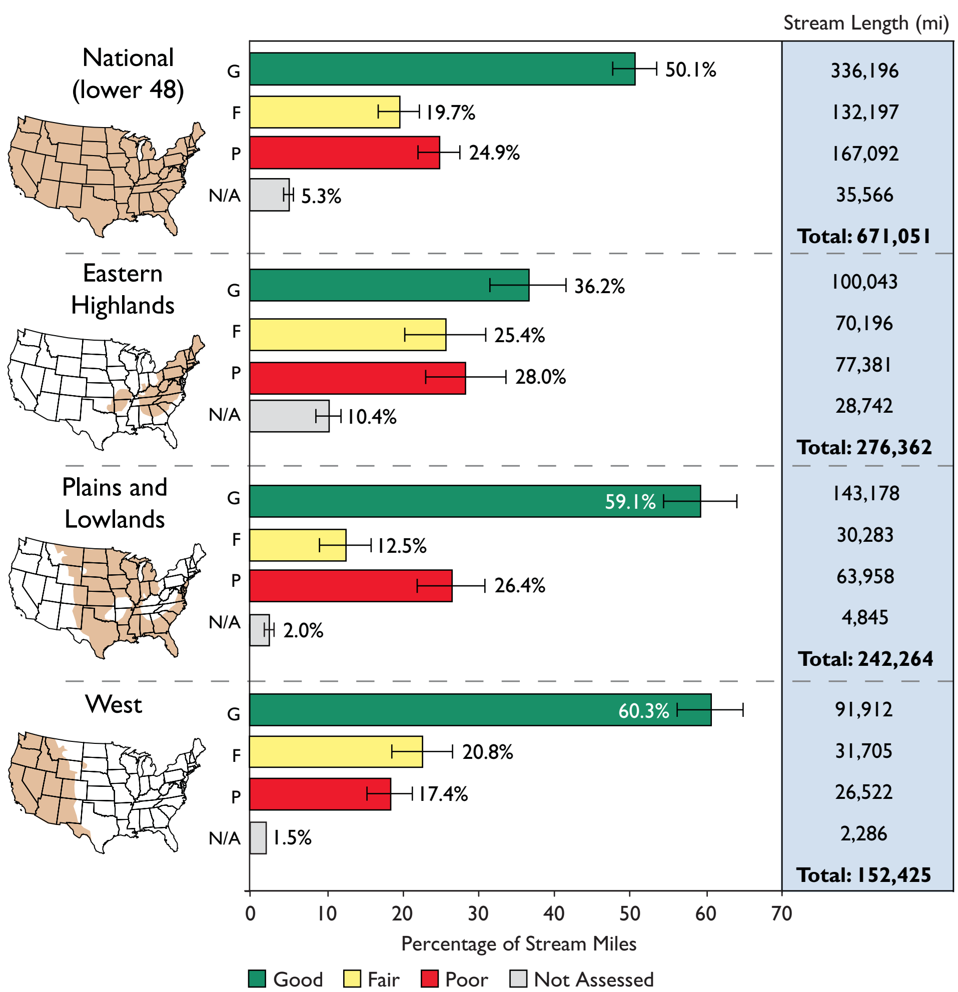


Figure 19. Streambed sediments in U.S. streams (U.S. EPA/WSA). This indicator measures the percentage of streambeds impacted by increased sedimentation, which indicates alteration from reference condition as defined by least-disturbed reference sites in each of the nine WSA ecoregions.

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

Findings for In-stream Fish Habitat

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

Riparian Vegetative Cover

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

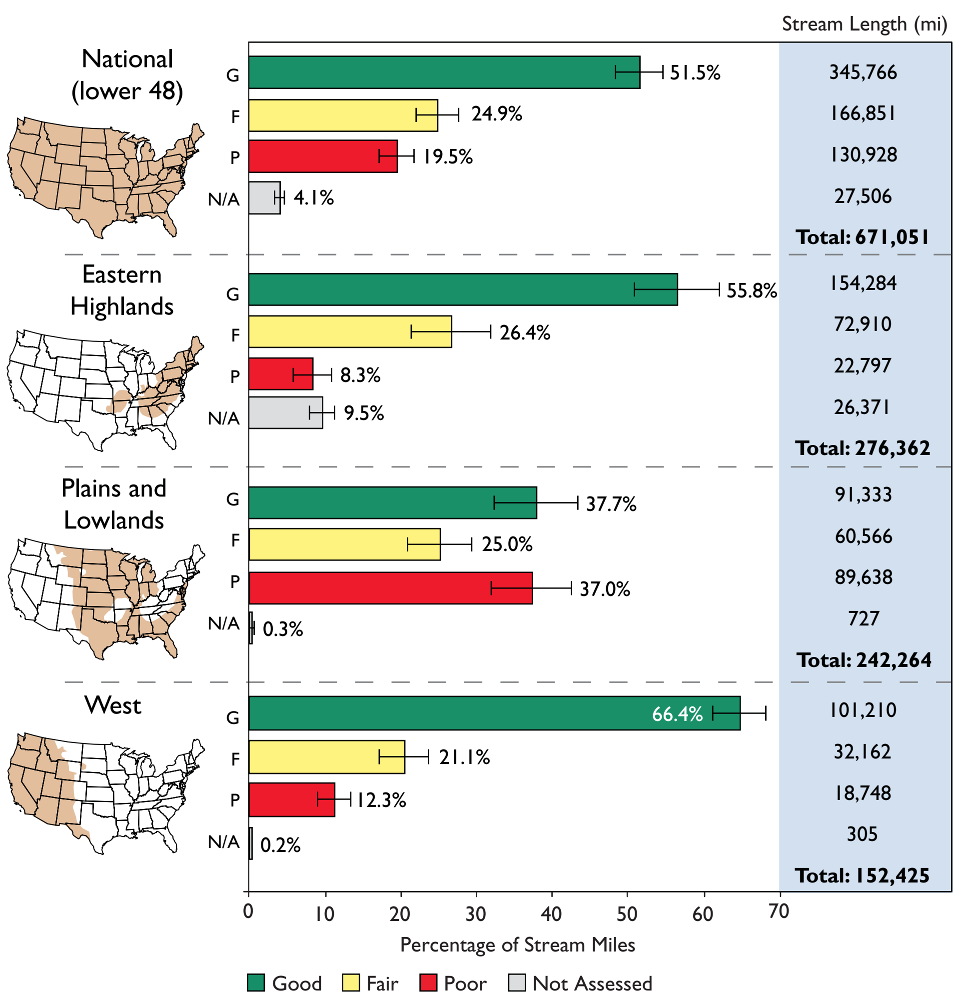


Figure 20. In-stream fish habitat in U.S. streams (U.S. EPA/WSA). This indicator sums the amount of in-stream habitat that field crews found in streams. Habitat consisted of undercut banks, boulders, large pieces of wood, and brush. Thresholds are based on conditions at regional reference sites.

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

Findings for Riparian Vegetative Cover

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

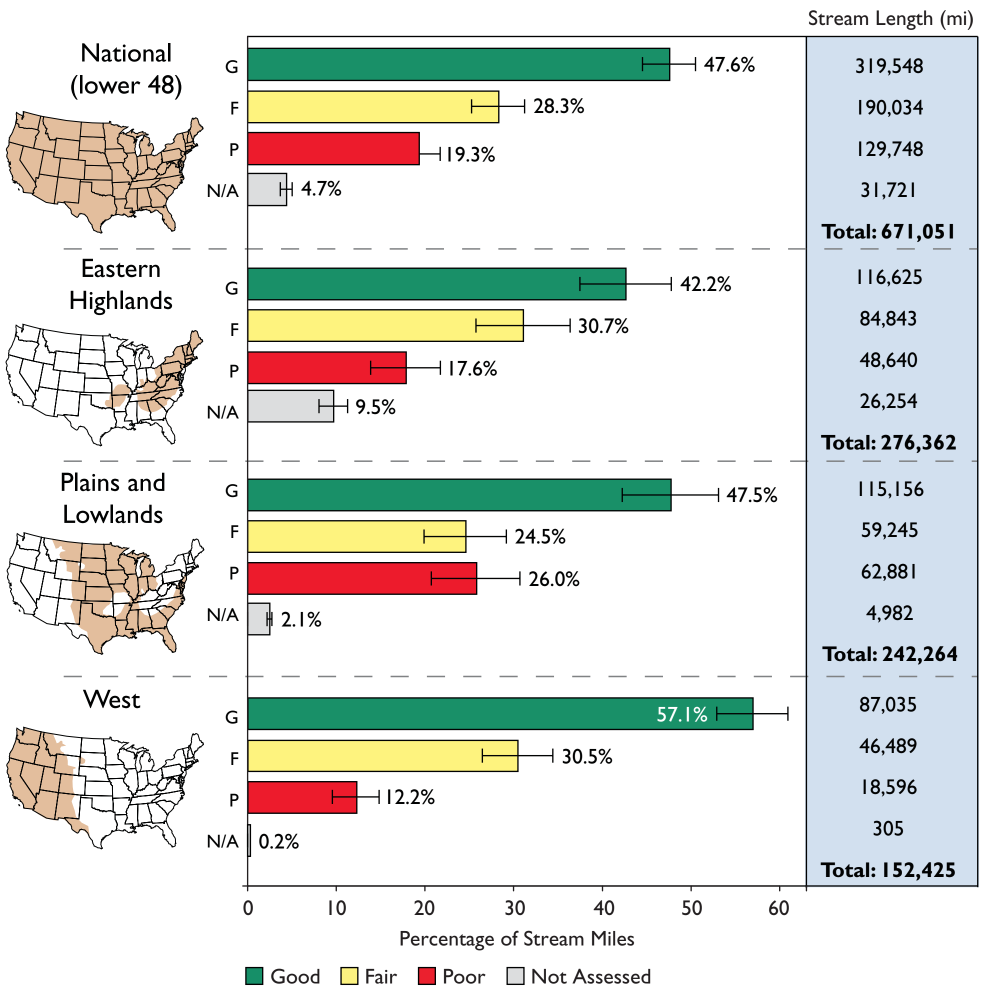
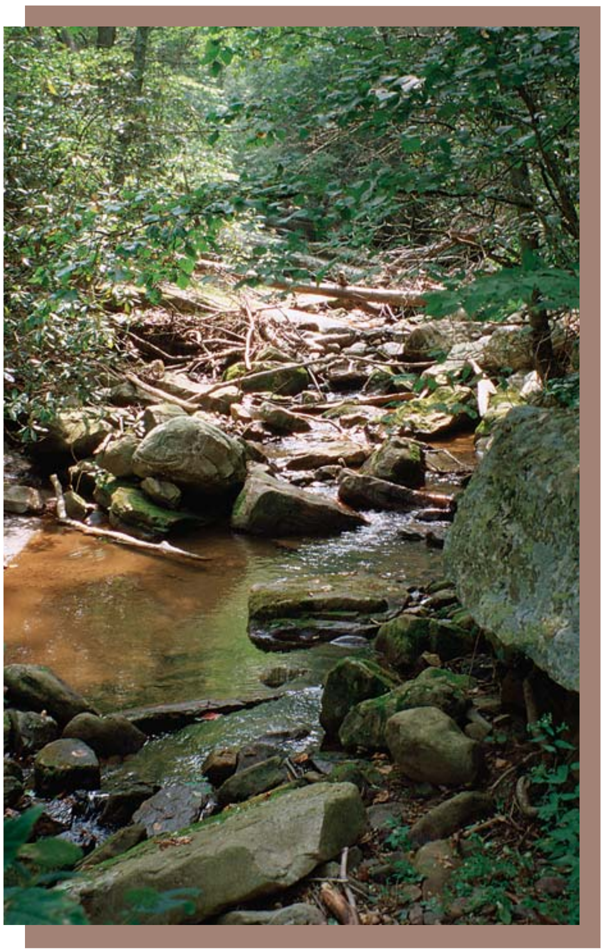


Figure 21. Riparian vegetative cover in U.S. streams (U.S. EPA/WSA). This indicator sums the amount of woody cover provided by three layers of riparian vegetation: the ground layer, woody shrubs, and canopy trees. Thresholds are based on conditions at regional reference sites.

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



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

Riparian Disturbance

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

Findings for Riparian Disturbance

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

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

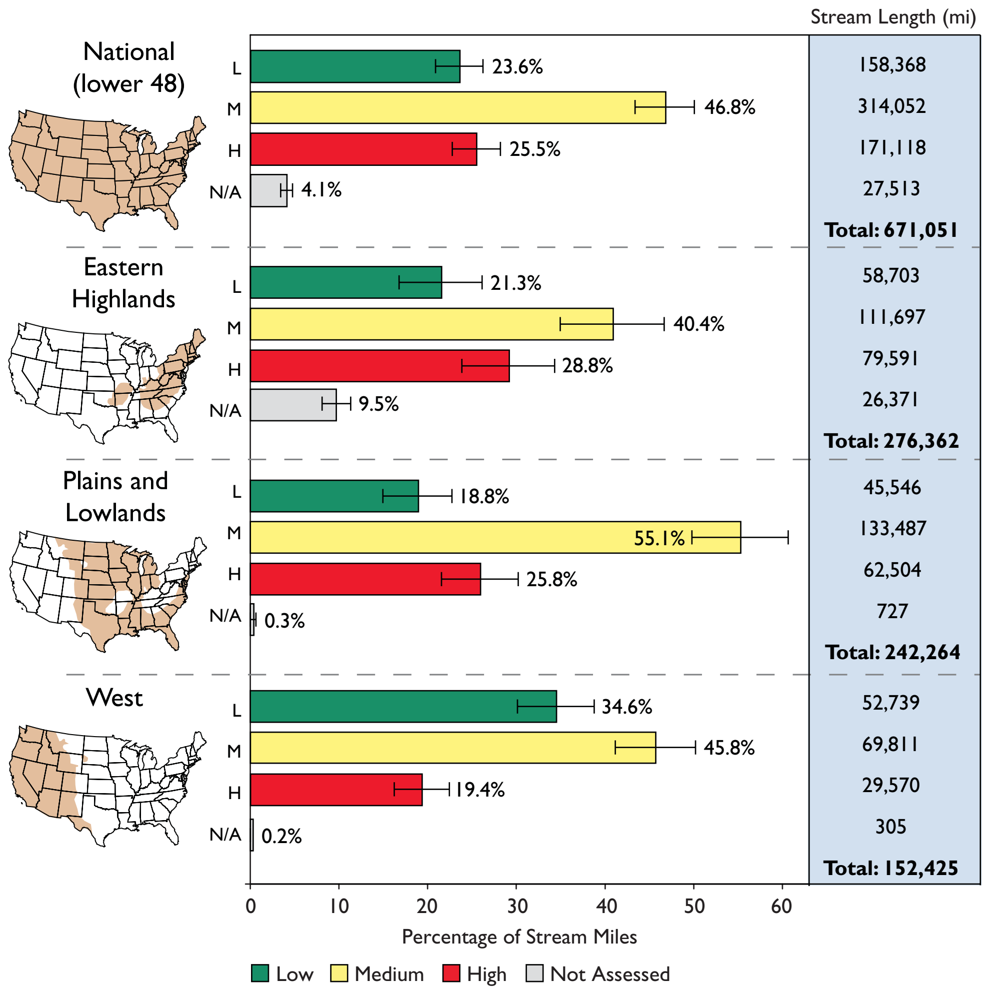


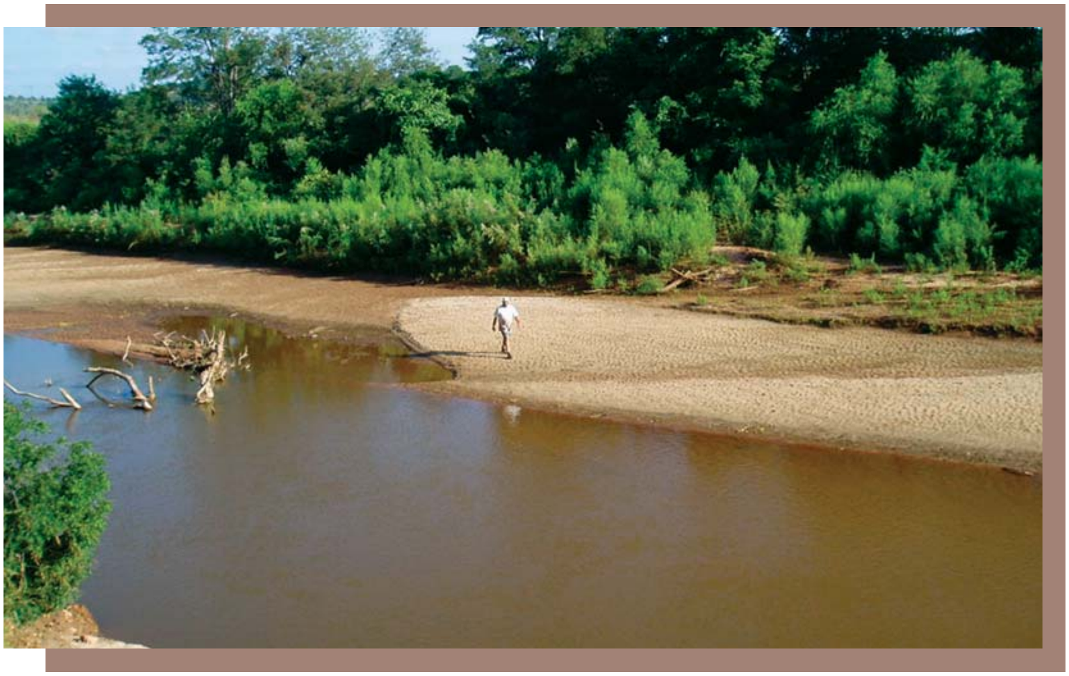
Figure 22. Riparian disturbance in U.S. streams (U.S. EPA/WSA). This indicator is based on field observations of 11 different types of human influence (e.g., dams, pavement, pasture) and their proximity to a stream in 22 riparian plots along the stream.

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

Biological Stressors

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

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



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

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

Ranking of Stressors

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

Extent of Stressors

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

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

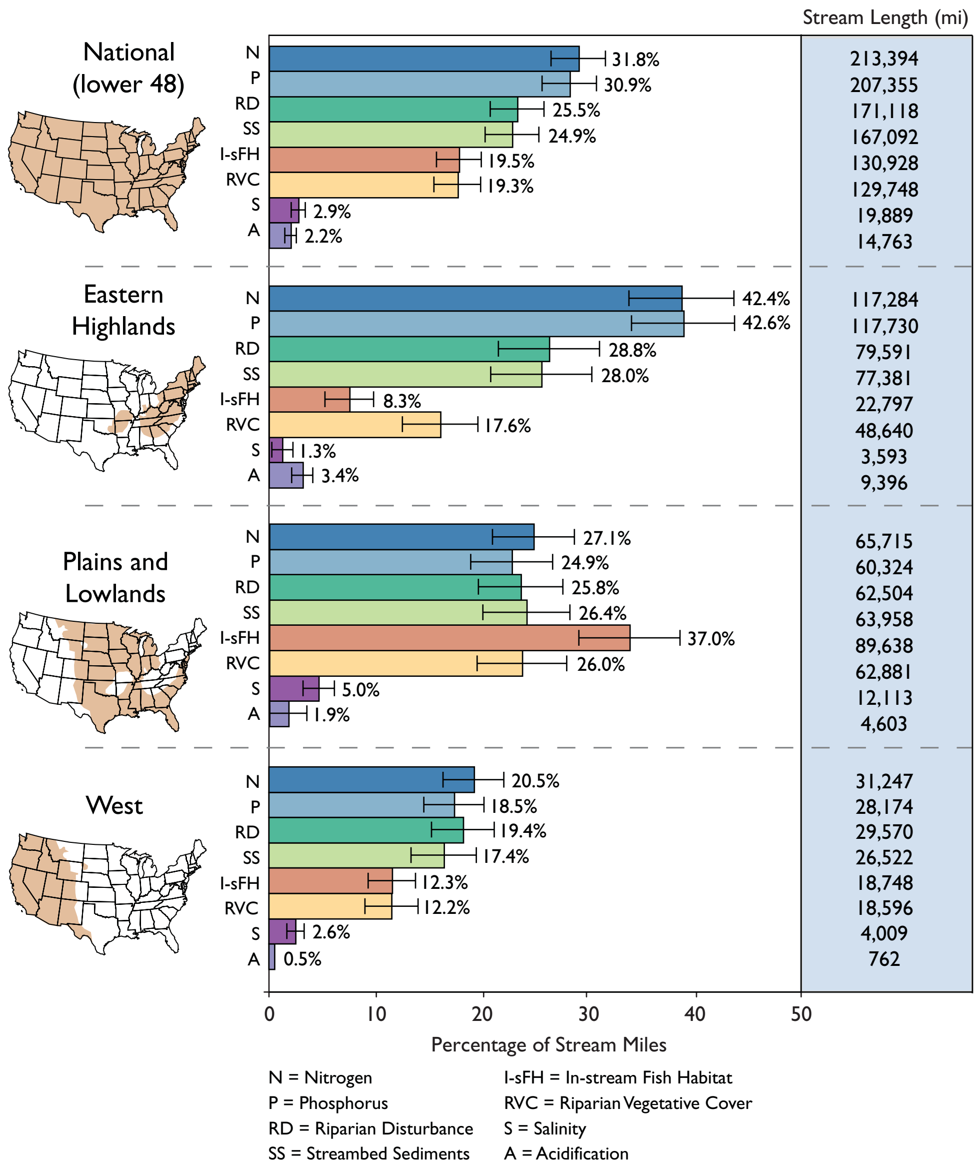


Figure 23. Extent of stressors (i.e., proportion of stream length ranked in poorest category for each stressor) (U.S. EPA/WSA).

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

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

Relative Risk of Stressors to Biological Condition

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

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

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

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

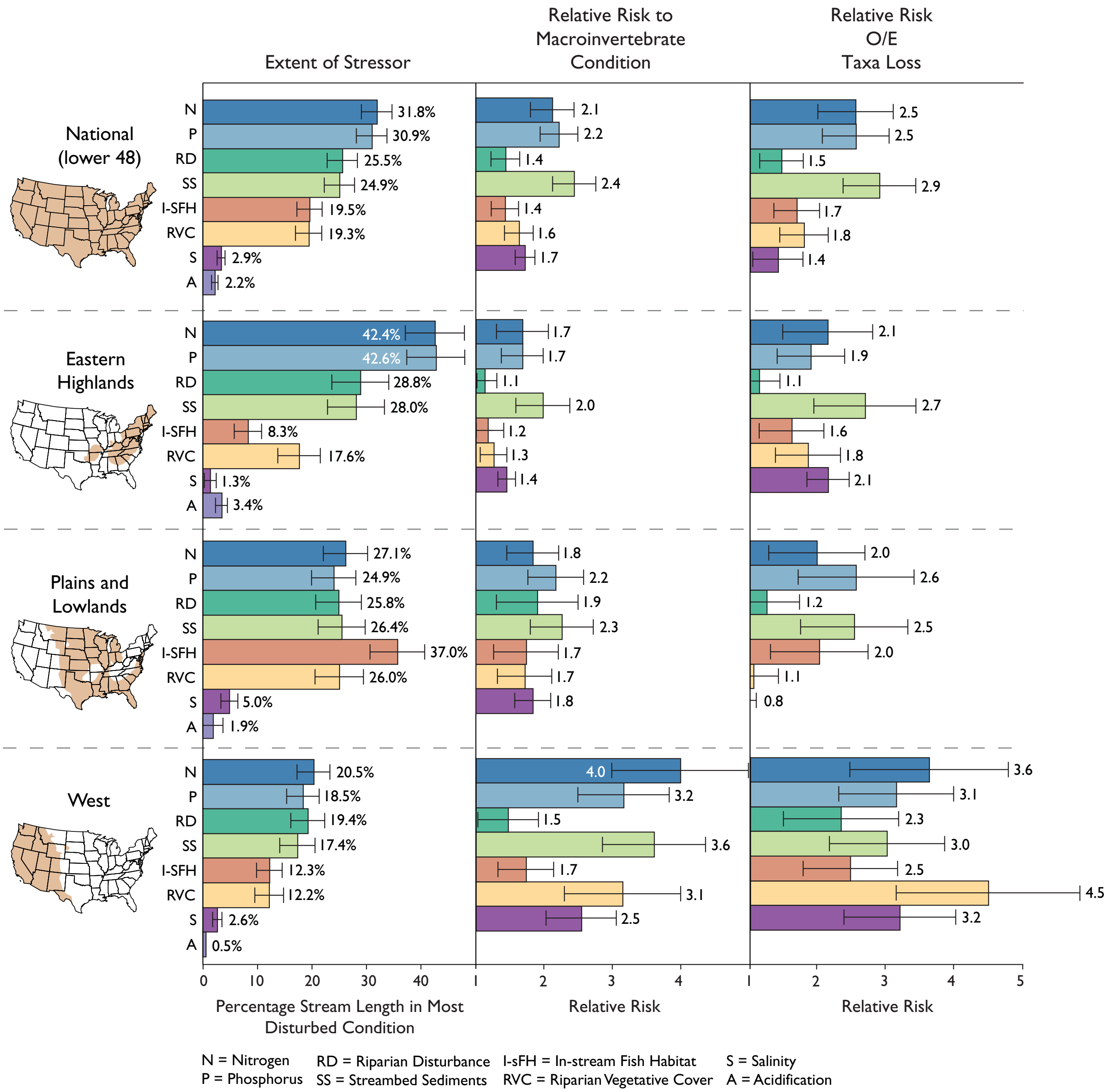


Figure 24. Extent of stressors and their relative risk to Macroinvertebrate Condition and O/E Taxa Loss (U.S. EPA/WSA). This figure shows the association between a stressor and biological condition and answers the question, "What is the increased likelihood of poor biological condition when stressor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

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

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

Combining Extent and Relative Risk

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

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

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

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