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Mid-Atlantic Highlands Streams Assessment

The Mid-Atlantic Highlands study region includes the area from the Blue Ridge Mountains in the east to the Ohio River in the west and from the Catskill Mountains in the north to Virginia in the south.

Cover Photo by: Alan Herlihy

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Mid-Atlantic Highlands Streams Assessment

by

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Notice

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Abstract

This report assesses the ecological condition of streams in the Mid-Atlantic Highlands and ranks the potential stressors affecting stream condition. This study used an innovative statistical survey, like a political poll, to sample almost 500 stream reaches throughout the Highlands. The report defines stream condition in terms of the health of the biological organisms in the stream, rather than just focusing on chemicals in the streams. The study, however, also measured stream chemistry as well as the physical habitat in which these organisms live. It found that a greater number of stream miles had biological organisms in poor condition than in good condition throughout the Highlands. Overall, 31% of the stream miles were in poor condition based on a fish Index of Biotic Integrity and 27% were in poor condition based on an aquatic insect index. Only 17% of the stream miles were in good condition based on the fish Index of Biotic Integrity while 25% were in good condition based on the aquatic insect index. For the first time, we have a benchmark for stream condition across the Highlands and a scorecard against which we can compare future changes in stream condition.

Key Words: assessment, stream, fish, aquatic insect, scorecard, management, Region 3, stressors, stream condition, biotic index, watershed, ecoregion.

Foreword

Water - the blood of life! If water is the blood of life, then streams are the arteries carrying that life-giving and life-sustaining fluid from the uplands to the estuaries. Streams have always been an integral part of our society. Streams were the highways for the western expansion in the early history of this country. From rafts and river boats moving people, goods, and materials to markets along the Susquehanna, Allegheny, and Ohio Rivers and their tributaries to providing life sustaining water for drinking and fish and wildlife, streams have sustained the life-blood of the Mid-Atlantic region and the nation.

Streams remain an important part of society today - for recreation, for navigation, for water supply, for peaceful, tranquil settings that provide a respite from the daily grind. The health of our streams is the responsibility of all our citizens, but to protect and manage these valuable resources, we need, first, to know their current condition. The innovative research study that is presented in this report provides us with that knowledge. Unfortunately, it is not good news. We have come a long way in controlling pollution and damage to our streams, but we still have a long way to go. We can make those improvements through programs like this that help us understand what the condition of our streams is, where the problems are, and what factors are contributing to those problems.

Unlike many previous studies that focused only on chemical pollutants, this study used a unique survey approach that emphasized the biological condition of streams. This project is the result of the joint efforts of many individuals and organizations and represents the way regional studies will be conducted in the future. The US Environmental Protection Agency Region 3 worked in conjunction with the states of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia, the EPA Office of Research and Development, the US Fish and Wildlife Service, local universities, and private contractors to design, collect, analyze, interpret and present this information. It is through the collective efforts of all these organizations and individuals that this innovative program was accomplished.

We now have a baseline of the condition of Mid-Atlantic Highland streams we can use to chart our progress in the future. We have a scorecard of current conditions and a way to generate future report cards on the condition of Highland streams. Through the concerted effort of all of us, we will continue to improve the health of our streams so that all our citizens can benefit and enjoy this unique resource.

Acknowledgements

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Executive Summary

The purpose of this report is to assess the ecological condition of streams in the Mid-Atlantic Highlands and to identify and rank stressors that might be affecting stream condition. The first step in managing the stream resources is to determine their current condition.

To provide this information, an innovative research, monitoring and assessment program was initiated. This program, called the Environmental Monitoring and Assessment Program (EMAP), used a unique statistical survey, like a political survey poll, to sample almost 500 stream reaches across the Mid-Atlantic Highlands during 1993 and 1994. This sampling occurred in partnership with the Mid-Atlantic States, the US Environmental Protection Agency Region 3, the EPA Office of Research and Development, the US Fish and Wildlife Service, multiple universities, and private contractors. One innovative feature of EMAP was that it used the health of biological organisms living in these streams to define the condition of the streams. It also sampled the physical habitat in which these organisms lived and the chemical quality of the water. This permitted an assessment of the condition of the Mid-Atlantic Highland streams and a ranking of the stressors or factors that were potentially affecting this condition. For the first time, we have a benchmark of stream condition across the Highlands and a scorecard against which we can compare future changes in condition.

STREAM CONDITION

What was the condition of the Highland streams? In general, the results of this assessment were not good news. Many streams throughout the Highlands were in poor condition. Over 31% of the stream miles in the Highlands were in poor condition based on a fish Index of Biotic Integrity and 27% of the stream miles in the Highlands were in poor condition based on aquatic insect indicators. Only 17% of the Highland stream miles were in good condition based on the fish Index and 25% were in good condition based on aquatic insects. More stream miles were in poor condition than in good condition.

FACTORS AFFECTING CONDITION

What factors might be contributing to these problems? The major stressor throughout the Highlands is habitat destruction. Urban sprawl and land use change are altering the landscape throughout the Mid-Atlantic region. Habitat destruction is occurring both in the stream and along the stream banks, removing trees and shrubs that provide cover for fish and other aquatic organisms. Some of the chronic problems that have existed for decades such as mine drainage and acid rain still persist. However, high nitrogen and phosphorus concentrations, which are major problems in other areas of the country, are not apparent in most Highland streams.

DIFFERENT PERSPECTIVES

Stream conditions do vary throughout the Highlands, however, and it is useful to look at stream condition from several different perspectives such as ecoregions, watersheds, or at the state level. These different perspectives help us see and understand what is and what is not working and why.

In the North-Central Appalachian ecoregion, for example, 43% of the stream miles were in poor condition based on fish indicators. If a watershed perspective were used, 41% of the stream miles in the Kanawha-Upper Ohio would be found in poor condition based on fish indicators. At the state level, West Virginia had 44% of their stream miles in poor condition based on fish indicators. Habitat destruction was still a major stressor in streams, regardless of the geographic perspective. Other stressors, however, varied depending on the geographic boundary. For example, mine drainage resulted in poor quality in 24% of the North-Central Appalachian ecoregion stream miles, but less than 1% of the stream miles in the Valley ecoregion had poor quality based on mine drainage. Although nutrients were not a problem throughout the Highlands, 20% of the stream miles in the Western Appalachian ecoregion did have high nitrogen concentrations.

A SCORECARD

A scorecard was developed for the condition of streams throughout the region, based on the different geographic areas and management perspectives. This scorecard provides a summary of stream condition and stressors and can be used to target areas for different protection, management, and restoration programs.

MANAGEMENT IMPLICATIONS

Some of the implications for protecting, managing and restoring streams in the Highland region included:

- ☞ You can't play the game without a scorecard.
- ☞ You can't develop a scorecard using existing monitoring networks.
- ☞ A single indicator only tells part of the story.
- ☞ Chemical indicators don't tell the whole story.
- ☞ Just one management perspective is not enough.
- ☞ You can't evaluate the success of management actions without repeated monitoring.

THE FUTURE

We now have a baseline of the condition of Mid-Atlantic Highland streams that can be used to chart our progress for the future. The scorecard can tell us where we need greater management attention for streams in poor condition as well as better protection for streams currently in good condition. Through the concerted efforts of us all, we can become good stewards of our stream resources and leave a legacy for future generations to enjoy.

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INTRODUCTION

PURPOSE

The purpose of this report is to:

1) Assess and report on the ecological condition of streams in the Mid-Atlantic Highlands (the Highlands).

2) Identify and rank the relative importance of **stressors*** affecting stream condition.

The Mid-Atlantic Integrated Assessment (MAIA) is an interagency, multidisciplinary research, **monitoring**, and **assessment** program to develop high-quality scientific information on the region's natural resources, current condition, stressors, trends, and vulnerabilities. MAIA results and information are intended to satisfy a broad group of stakeholders' needs, convey important information relevant to their assessment questions and issues, and be useful in making management decisions. Assessing the condition of the Mid-Atlantic Highland streams was a critical MAIA project. Information in this report is based on the scientific data, analyses, and results documented in the literature cited in Appendix A.

This report assesses Highland stream condition and ranks stressors.

BACKGROUND

The Mid-Atlantic Highlands encompass approximately 79,000 square miles and extend from the Blue Ridge Mountains in Virginia in the east to the Ohio River in the west, and from the Catskill Mountains in the north to the North Carolina-Tennessee-Virginia state borders in the south (see inside front cover). West Virginia is the only state entirely within the Mid-Atlantic Highlands. The Highlands contain many unique natural features that combine to form a complex, interconnected mosaic of terrestrial and aquatic **ecosystems**. Streams run through forests interspersed with **wetland**, residential, and agricultural areas and integrate contributions from all types of **land use** and **cover**. The Highland **landscape** contains diverse hard-wood forests, as well as many rare, **threatened** or **endangered** plant and animal species. The Shenandoah National Park, which lies within the Ridge and Valley Province, is world renowned for its beauty and variety of animal and plant life.

In addition to providing a home for a unique variety of plants and animals, the Highlands are also home to approximately 11.5 million people. Residents of the Highlands can leave the hustle and bustle of an inner city business at the end of the work day and enjoy rural settings less than an hour away. They can find tranquility while fishing a Highland stream or hiking a mountain trail. A system of roads and interstate highways (see inside front cover) allows them to enjoy the best of both worlds: natural settings and vibrant, active cities.

Human desires for nature and civilization can be at odds with one another. The same roads and highways that provide a bridge between the two worlds pose a potential threat to the ecosystems surrounding them: road construction contributes to soil erosion and the siltation of streams (Figure 1); vehicular traffic contributes to air pollution and adds contaminants to the highways

Terms in the glossary are* **bolded *at first usage.*

Photo courtesy of EMAP

Figure 1. Road construction can contribute suspended sediment to streams during and following rain storms.

that subsequently wash into streams during storms. We depend on the electrical energy provided by coal-fired boilers, as well as the use of agriculture fertilizers and chemicals to increase the production of food and fiber for our nourishment and survival. Some of the ecological effects associated with these human activities include the accumulation of trash in streams, drainage from mines and **mine tailings**, **nutrient** runoff, and stream **channelization** (Figure 2).

We are faced with a daily dilemma: we want ready access to the conveniences of modern society, and we want to sustain environmental quality because it provides links to our cultural past and inner peace. People with different, sometimes opposing, perspectives are asking, “How do we provide goods and services to society in an environmentally sound manner?” The first step toward deciding this is to simply, but objectively and rigorously, assess the current status of our ecological resources - where are we right now? With this perspective and baseline, our social and political institutions can assess where we are, where we want to be in the future, and what actions are needed to move us in that direction. An assessment of the ecological condition of streams in the Mid-Atlantic Highlands is one of the first steps in this process.

Stream Condition

Most historic assessments of stream quality have focused on describing the chemical quality of streams and, occasionally, on sport fisheries impacts. As we have made progress in controlling chemical problems it has become obvious that the ultimate concern is actually the health of the plants and animals that inhabit these streams and rivers.

In this assessment we have tried to address this concern not by ignoring physical and chemical measurements, but by shifting the focus to direct measurements of the **biota** themselves. In this assessment, the ecological condition of

INDICATORS:

- An indicator is a sign that relays a complex message in a simplified and use ful manner.
- An ecological indicator is a measure that describes the condition of an ecosystem or one of its critical components.

Example – The presence of trout in a stream indicates cool, well-oxygenated water, with lots of aquatic life; therefore, the presence or absence of trout is an indicator of stream condition.

Photo courtesy of EMAP

Figure 2. Unauthorized dumping, mine drainage, logging, management practices, and similar human activities can lead to degraded stream quality.

streams is defined by biological indicators. The biological organisms in a stream integrate the many physical and chemical stressors and factors, including other biota (**parasites, predators, or competitors**), that are acting in, and on, the stream ecosystem. Stream condition can be determined by assessing appropriate biological indicators (Table 1), or combinations of these indicators, called indices. Information on the ecological condition of streams is supplemented by measurements of other stream characteristics, especially those physical, chemical, or other biological factors that might influence or affect stream condition. These stream characteristics allow us to assess the stressors of stream condition, based on expected signals from major environmental **perturbations** (e.g., habitat modification, mine drainage, acid rain, agricultural nutrients, etc.). The combination of ecological and stressor indicators listed in Table 1 represents our best current understanding of the biological, physical and chemical factors that collectively determine stream quality.

Historic assessments of stream quality were limited and too narrowly focused on chemicals.

Working in partnership with the states (Delaware, Maryland, Pennsylvania, Virginia, and West Virginia), the U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), multiple universities, and Environmental Protection Agency (EPA) Region III, the EPA Environmental Monitoring and Assessment Program (**EMAP**) assembled crews in 1993 and 1994 to collect samples on 448 **first- through third-order streams** (see pp. 6-7 for definition) across the Mid-Atlantic Highlands. All of the crews had been trained to use identical **sampling methods**, so that comparisons across the region could be made.

Perhaps the most unique aspect of this assessment is that it uses data from a regional statistical survey of streams to describe the condition and characteristics of the entire **population** of first - through third - order streams in the Mid-Atlantic Highlands. It is intended to answer, as directly as possible, the question, “What is the condition of Highland streams?”

Table 1

Examples of ecological indicators measured in Highland streams.

Indicators of Condition	**Purpose**
Fish	Important indicators of stream condition; middle to upper end of **food web**; accumulate contaminants that are then consumed by humans, other mammals, and birds. **Caution:** Some smaller streams may naturally not have fish. No fish in small streams does not automatically mean there are problems.
Aquatic insects	Indicators of stream condition and sensitive to environmental factors such as pollutants, pH, and loss of **algae**. Insect populations can recover rapidly when conditions improve.
Indicators of Stress	**Purpose**
Water chemistry	Chemical criteria and standards established for envionmental and human health; nutrients and contaminants affect aquatic insects and fish
Stream channel sedimentation	Sedimentation can smother algae and plants, aquatic insects, and fish feeding and spawning areas.
Riparian habitat	Stream bank alteration (removal of trees, shrubs, grasses, change of grade) affects channel habitat structure, aquatic insects, and fish
Fish tissue contaminants	Contaminants accumulate in fish tissue, and can adversely affect humans and wildlife
Watershed condition	Different land uses can adversely affect stream biology, chemistry, and physical habitat

In this assessment, stream condition is defined by the health of the living organisms.

Regional Statistical Surveys

In the past, EPA and the states addressed municipal and industrial **point sources** of chemicals as major threats to streams and rivers. This led to focusing monitoring, assessments, and controls very locally on individual segments of streams above and below point source discharges. Monitoring locations were selected to evaluate the effectiveness of improved treatment of these municipal and industrial discharges. As these point sources were cleaned up, it became apparent that a wider range of stressors also was threatening our aquatic resources. Some attempts were made to combine existing data and use them in regional assessments, but the limitations of this approach became apparent because the local sites were not representative of other streams or areas in the region. Another approach was needed to assess stream quality on a regional basis.

EPA's EMAP develops indicators and other research tools to track status and trends in the condition of the nation's ecological resources. These resources include estuaries, wetlands, inland lakes and streams, forests, and mixed landscapes.

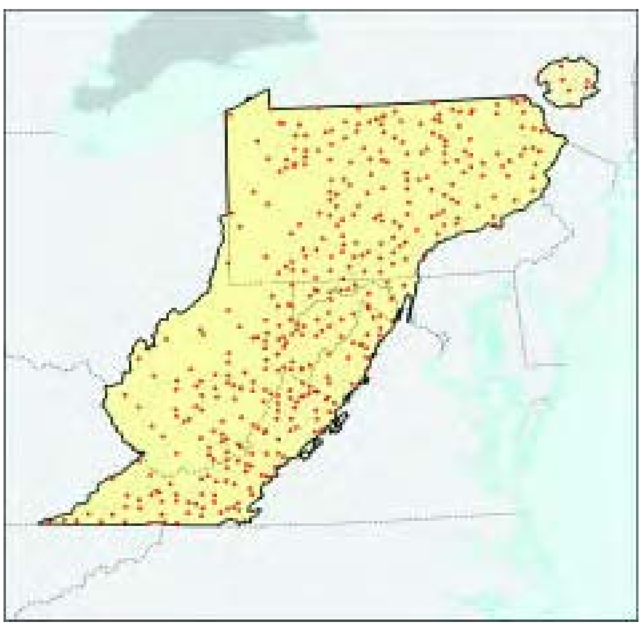


Figure 3. Statistically selected stream sites permit objective estimates of stream quality. About 450 stream reaches were sampled in the Highlands during 1993 and 1994.

EPA and the states in the Highlands wrestled with this problem and came up with a different approach for stream monitoring. In addition to implementing direct measures of the ecological condition of the biota themselves, they devised a way to pick monitoring locations that do not focus on known problem areas (e.g., sewage outfalls). Instead, monitoring sites were chosen through a statistical approach that provides a clear and objective view of the condition of all streams. It is hoped that this approach, and this assessment, can serve as models for future National Water Quality Inventories: A Report to Congress (also known as the 305[b] Reports, after the section of the Clean Water Act that mandated the reports).

To describe the condition of all streams within the Highlands, without sampling all of them, EMAP worked with EPA Region III and the states to develop a regional statistical survey of streams, with the goal of providing statistically unbiased estimates of stream condition throughout the Highlands (Figure 3). With this approach, we can describe the condition of the streams, the proportion of stream miles that are impaired or degraded biologically, and characterize the relative importance of stressors, such as mine drainage or stream sedimentation.

A statistical survey of streams operates in the same manner as the public opinion polls used to project winners and losers of political campaigns. A subsample of **stream reaches** is selected at random to represent the population of streams in a region, just as the subsample of individuals in a public opinion poll is selected to represent the voting population as a whole. Regional statistical surveys have been used for many years in forestry and agricultural monitoring programs to determine the condition of forests and agricultural lands, but their use in assessments of aquatic ecosystems is just beginning. Additional information on the EMAP stream design can be found in the references listed in Appendix A.

The Highland Stream Population

Historically, management practices have focused on large streams, which are best known to the public due to their use in navigation and boating, and their visibility from major road crossings. Small streams, on the other hand, dominate the total stream length in the region, contribute to the quality and condition of larger streams and rivers, and are critical to determining the condition of all Highland streams and rivers.

Small, first-order streams are the dominant stream class in the Highlands; over 51,000 stream miles (i.e., 63% of the total length) are classified as first-order streams (Figure 4). Second-order streams are larger and start at the point where two first-order streams join. Over 12,000 stream miles in the Highlands (i.e., 15%) are in second-order streams. Third-order streams consist of two

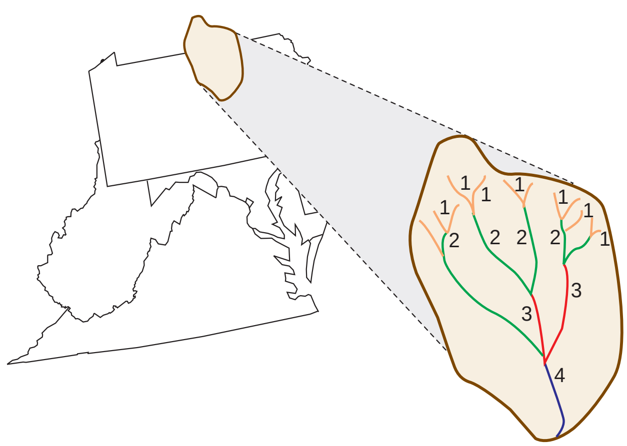


Figure 4. The majority of streams in the Mid-Atlantic Highlands (i.e., 89% or 72,200 stream miles) are classified as first- through third-order streams. This stream classification is illustrated above for one hypothetical **watershed** in the Highlands. The confluence (joining) of two first order streams forms a second order stream; the confluence of two second order streams forms a third order stream, etc. (See Strahler 1956 for more information.)

(or more) second-order streams coming together and about 8,850 stream miles in the Highlands (i.e., 11%) are in third-order streams. All higher-order streams (i.e., fourth-order and higher) constitute only 11% or 8,000 stream miles.

Small streams are an important Highland resource. 63% of the stream miles are in headwater streams.

The size or order of a stream not only affects its natural characteristics, but also its capacity to handle both point source and **nonpoint source** pollutants. Stream size frequently affects the size and type of biotic community present, particularly for fish, and may control the relative importance of factors to which the biota respond. Very small streams (first-order, **headwater streams**) are often quite clear and shaded by trees; they are likely to be dominated by aquatic insects in the stream bottom and with small fish that feed on these bottom organisms. Large streams (sixth- to seventh-order rivers) are often muddy with canopy cover only along the banks and are dominated by larger fish that feed along the shoreline. While streams larger than third order are not covered in this assessment, this continuum in stream size and characteristics is an important controller of what we expect to find in streams of different sizes (Figure 5).

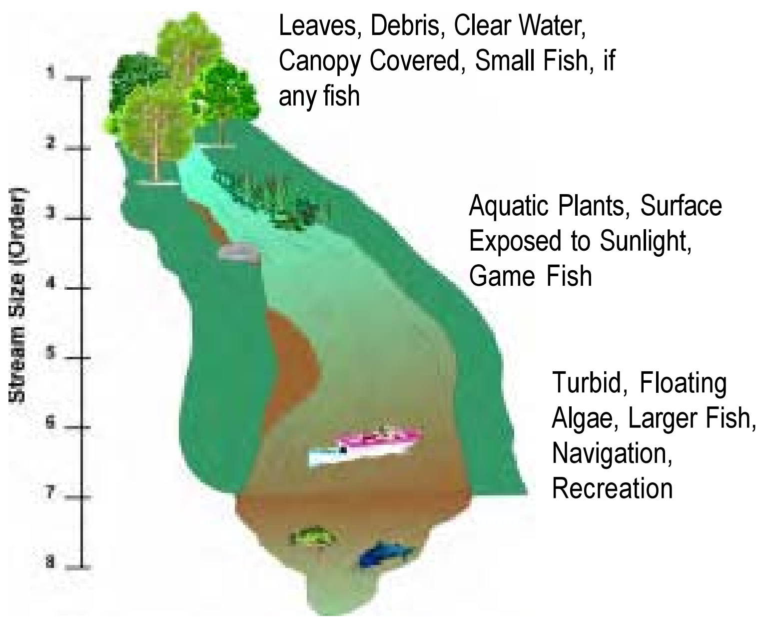


Figure 5. Streams change their characteristics as their size or order increases. Smaller first- to third-order streams dominate in the Highlands. Their quality is critical to sustaining the quality of larger rivers.

The stream network used for selecting sampling sites in this assessment, and for estimating the total length of streams in the region, was the EPA River Reach File, Version 3. This digital database includes all streams that are represented on USGS maps at a **scale** of 1:100,000. The **map scale** used is important because it can affect the estimate of stream miles. The stream network shown on 1:100,000 scale maps was considered a good **index** of the population of Mid-Atlantic streams.

Ecological Condition of Streams

To assess the overall condition of Highlands streams, we looked at multiple biological, chemical, and physical indicators. To answer the specific question "**What is the ecological condition of Mid-Atlantic Highland Streams?**" we rely on direct measures of the biological **communities** that inhabit the streams. Throughout this report, ecological condition - good, fair, or poor - is determined by biological indicator or index scores. The fish, aquatic insects, and other animals and plants in a stream serve as "integrators" of all the stressors to which they are exposed. The fish and insects respond to the cumulative effects of chemical contaminants, modification of their physical habitat, and changes in both the amount and the timing of the flow of water. Historically, sport fish (e.g., trout, smallmouth bass) have been the primary biotic component of interest to the public, and an emphasis has been placed on the condition of sport fisheries in larger rivers. This emphasis on sport fish and large rivers has resulted in a narrow, incomplete view of the status of Highland streams, where large rivers make up only about 10% of the total stream length. Some people have defended this large river/sport fish perspective by claiming that small streams do not support fish. On the contrary, we find that headwater streams can be very important in providing suitable habitat for both fish (e.g., minnows, chubs) and sport fish (e.g., brook trout, smallmouth bass) (Figure 6). One interesting exercise to put this number in perspective is to assume that all fourth - order and larger streams have sport fish present. If so, then second -, third-, and fourth and larger - order streams all have approximately the same total length with sport fish present (8,100, 8,200, and 8,900 miles, respectively). We estimate first-order streams have nearly twice those lengths (i.e., 14,300 miles) with sportfish.

Biological organisms integrate all of the stressors to which they are exposed. Their health defines stream condition.

By sampling both fish and aquatic insect assemblages throughout the Highlands, we have the opportunity to move beyond a narrow, sport fisheries focus, and look instead at the biological integrity of stream ecosystems. Biotic integrity has been defined as, "the capacity of an ecosystem to support and maintain a biota that is comparable to that found in natural conditions." Most people

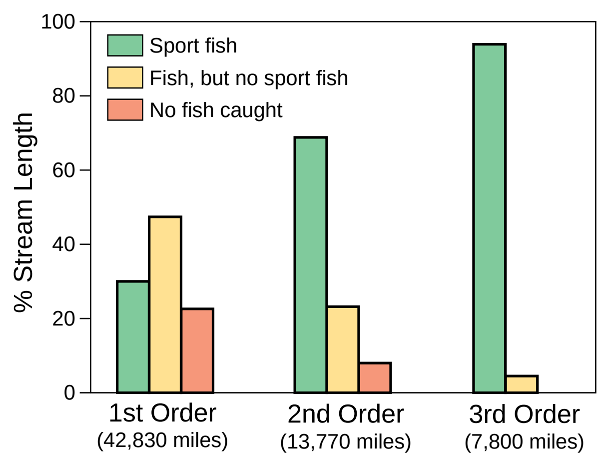


Figure 6. Fish distribution in 90% of Highland streams (i.e., first through third order), by stream order. Even first order streams have sport fish.

would agree (as would the stipulations of the Clean Water Act) that maintaining the biotic integrity of streams is a worthy goal. This assessment is one of the first steps toward achieving that goal.

Fish Assemblages

Streams must meet a number of requirements if they are to support healthy fish assemblages - providing a sufficient variety of foods, clean bottom gravel for spawning, and a habitat with diverse forms of fish cover, among others. In analyzing the Highlands fish data, a series of indicators, or metrics, was used to measure how well the stream is meeting these requirements. Examples of fish metrics are: the number of fish species present who cannot tolerate pollution; the proportion of individuals present that require clean gravel for spawning; or the number of bottom vs **water column** species present. Each **metric** was scored against our expectations of what **value** was possible for each stream (based on reference conditions - see box), and then combined to create an overall Index of Biotic Integrity (IBI), whose values range from 0 to 100.

Reference Condition

In order to measure the biotic integrity of streams, we must rely on some estimate of the streams' reference condition. This is the minimally disturbed, or "natural", condition referred to in the definition of biotic integrity (see text). In order to understand how we approached estimating reference condition in MAHA, it's useful to employ an analogy with which we are all familiar. Suppose that you wanted to use human body temperature as an indicator of human health (as is commonly done). One of the first things you would need is information on the normal range of temperatures. In order to estimate this range, or distribution, you might draw a subsample of the human population that is validly 'healthy.' The range of temperatures measured in this subsample is an estimate of reference condition for this indicator. Next, we'd want to know how far away from this distribution (or how extreme) a temperature needs to be before we'd consider it to be unhealthy. In the case of body temperature, we might have very high confidence that we've correctly identified a healthy subpopulation, and the range of temperatures might be fairly small. In this case, we could use something like the ends or extreme values from the reference distribution (e.g. the lowest 5% or highest 5% of body temperatures measured from a large group of people), as thresholds beyond which we identify a temperature as unhealthy. We use a similar approach for the biological data we report in MAHA - identifying a healthy subsample of sites, collecting indicator information at each one, and describing a distribution of reference condition values - but have less confidence that all of the sites we identify as 'healthy' truly are. For this reason, we use more conservative thresholds than we used in the body temperature example. Commonly, the 25^{th} percentile value (of the reference distribution) is used as a threshold between sites in good condition, and those in fair, or marginal, condition. We also adopt the 1^{st} percentile as the threshold between sites in fair condition and those in poor condition. For these sites, we can be 99% confident that their biotic integrity values are below anything found in our subsample of sites in minimally disturbed, or natural, condition.

> ***Using fish indicators, almost twice as many Highland stream miles were in poor condition (31%) as in good condition (17%).***

The definition of biotic integrity described above introduces the concept of "natural conditions" against which each stream's biotic integrity should be compared. Our best description of natural conditions is derived from measurements made at reference sites. For MAHA, we established a small collection of sites that represent the best conditions that are observable today, i.e., sites that are free of influences from mine drainage, nutrients, habitat degradation, etc. The IBI scores calculated for these sites range from 57 to 98; this range describes a distribution, which we use to estimate reference conditions for the Highlands region (see box). The 25th percentile of this distribution (72) is the value we use to distinguish sites that are in good condition from those in fair condition. The 1st percentile value (57) separates sites in fair condition from those in poor condition. Another way to describe (statistically) this setting of thresholds is to say that we are 99% certain that any value less than 57 is below the range of values we see in reference sites. For more information on the development of the Highlands fish IBI, and the setting of thresholds, please see the references listed in Appendix A.

In the Highlands as a whole, approximately 17% of the stream length is considered to be in good condition; that is, 17% of the Highlands stream length had IBI scores greater than 72 (Figure 7). 36% of the stream length was in fair condition,

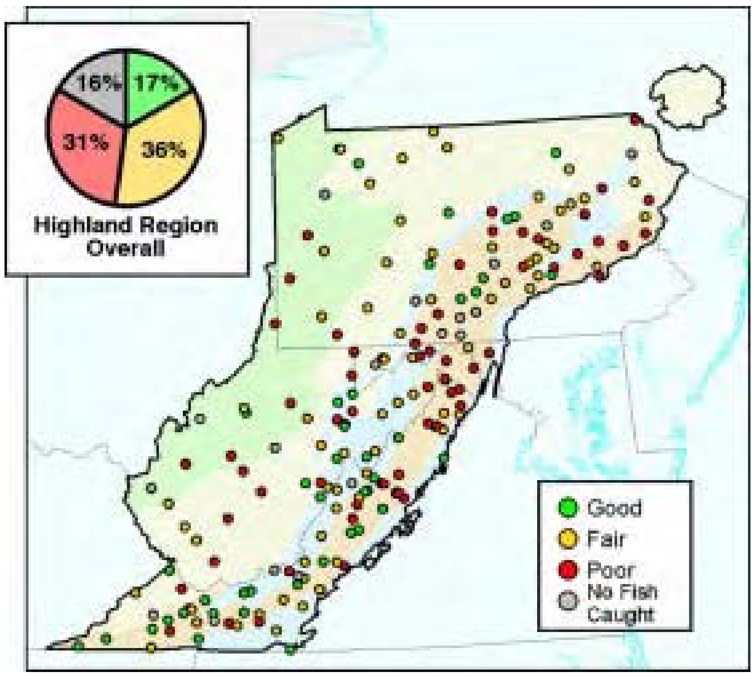


Figure 7. Fish IBI scores in Highland streams showing the proportion of the stream miles in good, fair, and poor condition. Red, yellow and green markers on the map correspond to individual sites in poor, fair or good condition. About 31% of the Highland stream length has poor fish assemblages, relative to those found in reference sites. Streams with 'no fish were caught' were sampled, but most are too small for us to predict reliably whether they should be expected to have fish. Within the Highland region are subareas that represent management areas such as ecoregions (shaded areas above), watersheds and states. These are discussed in later sections.

and 31% was in poor condition; that is, 31% of the stream miles have IBI scores less than 57 (Figure 7). About 16% of the Highlands stream length drains watersheds that are too small for us calculate an IBI reliably. Most of these streams had very few (or no) fish collected, and may be too small for us to expect to find healthy fish populations present.

Aquatic Insect Assemblages

An additional picture of stream condition can be derived from examining the aquatic insects (and other bottom-dwelling invertebrates) in streams (Figure 8). These animals provide food for fish and other wildlife, and serve as a link between plants and higher levels of the food web. One aquatic insect index, EPT, has been used extensively to evaluate stream condition throughout the United States. It is calculated from the number of **species** that are found in three **orders** of aquatic insects - mayflies (***E****phemeoptera*), stoneflies (***P****lecoptera*), and caddisflies (***T****richoptera*); the index gets its names from the first initials of these three orders (**EPT**). Many of the species in these three orders are sensitive to pollution and other stream disturbances, and the total number of species is a good gauge of how disturbed any given stream may be. EPT scores from least-disturbed Highland streams were used to set expectations (very analogous to the best attainable condition perspective for the fish IBI). Expectations were set separately for streams with fast-moving sections or "riffles" (the vast majority of Highlands streams) and slow-moving streams where "pools" dominate, because fewer EPT species naturally occur in pools. For riffles, 75% of the least-disturbed streams had at least 17 species of EPT present, so we used this as our definition for good condition. In pools, the corresponding number of EPT species was 6. The remainder of the least-disturbed streams had between 9 and 16 species (riffles) or 3-5 species (pools), so we used these criteria to define fair condition. All streams with fewer than 9 (riffles) or 3 EPT species (pools) were classified as in poor condition.

Photo courtesy of EMAP

Figure 8. Sampling aquatic insects during May-July in Highland streams. Biological organisms are used to define stream conditions.

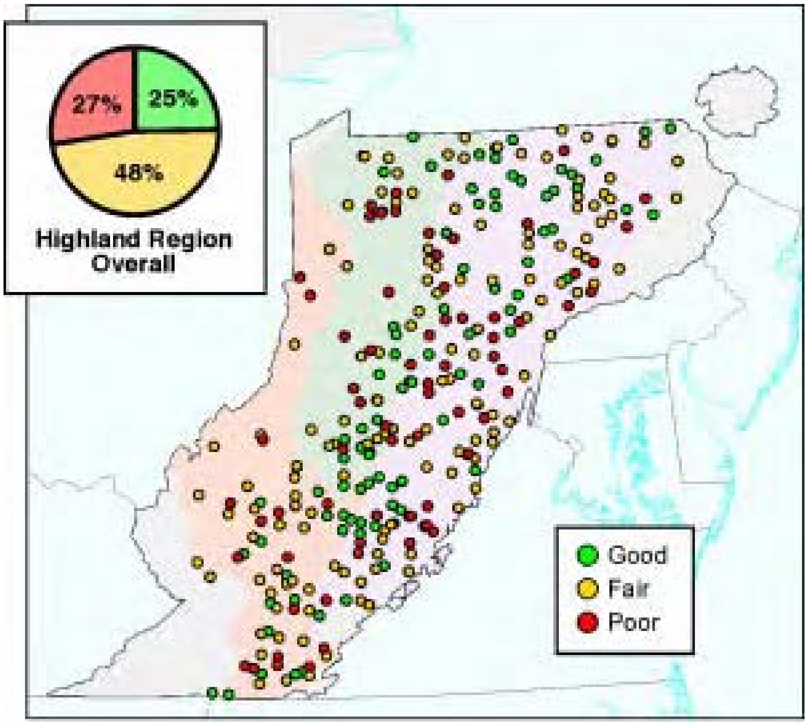


Figure 9. About 25% of the Highland stream miles are in good condition based on the aquatic insect index (EPT). 48% were in fair condition and 27% were in poor condition. (Note: management can also occur within watersheds, which are shown here in different shades and discussed in a later section.)

For the Highlands region as a whole, 25% of the stream length was in good condition with respect to the EPT index (i.e., 25% of the stream miles had 17 (riffles) or 6 (pools) or more EPT species present). 48% of the stream length was in fair condition, and 27% was in poor condition (Figure 9).

Comparison of Fish and Aquatic Insect Scores

Differences between estimates of ecological condition based on fish and aquatic insects are expected, because these two groups of organisms respond to different disturbances in the environment. This expectation is borne out in this Highlands assessment, where fish IBI scores indicated about 31% of the Highland stream length was in poor condition (using the best attainable reference perspective), while the EPT index indicated about 27% of the stream miles were in poor condition (Table 2). Such differences can be attributed to a number of factors. As already stated, fish and aquatic insects are expected to respond differently to stresses, and the differences in the relative scores of the fish and aquatic insect scores in different areas of the region (where different stresses are known to dominate) may be indicative of this.

Using insect indicators, 27% of Highland stream miles were in poor condition and 25% in good condition.

Table 2

Comparison between fish index scores and aquatic insect scores for the condition of stream miles in the Mid-Atlantic Highlands.

Area	% Stream Miles in Poor Condition	
	Aquatic Insects	Fish Index
Highlands Region		
Good	25	17
Fair	48	36
Poor	27	31
Not Estimated	0	16

Because the fish and aquatic insect groups respond differently to different stressors, it is important that we do not rely on just one index. We run the risk of missing some problems if we use just one or the other.

Although there are differences, both indices indicate over one quarter of all stream miles in Highland streams are in poor condition. Why?

Both fish and insect indices indicate over 25% of Highland stream miles are in poor condition.

STRESSORS

In the previous section, the ecological condition of the streams in the Mid-Atlantic Highlands was described based on direct measurements of stream biota. Here we present our findings on the stressors to the streams of the Highlands region. These are based on direct measures of physical, chemical or biological characteristics of streams and their watersheds. There are stream **attributes** that can be directly or indirectly altered as a result of human activity or intervention in the stream system, and that have been known to have harmful effects on stream biota. They are described as "potential" stressors because analyses to date have examined only the extent and distribution of these stressors. We have yet to establish the statistical relationships between these stressors and the biological conditions described above. We present this information in the belief that comparisons of stressors will be useful to regional managers in determining where best to focus their limited resources for stream protection and restoration, when it is warranted. Additional technical information on the stressors and their measurement can be found in the references listed in Appendix A.

The heterogeneous nature of the land use and land cover in the Mid-Atlantic Highlands is evident from satellite imagery (Figure 10). Agricultural areas, urban and suburban clusters, forests, mining sites, and other features are interwoven into the landscape.

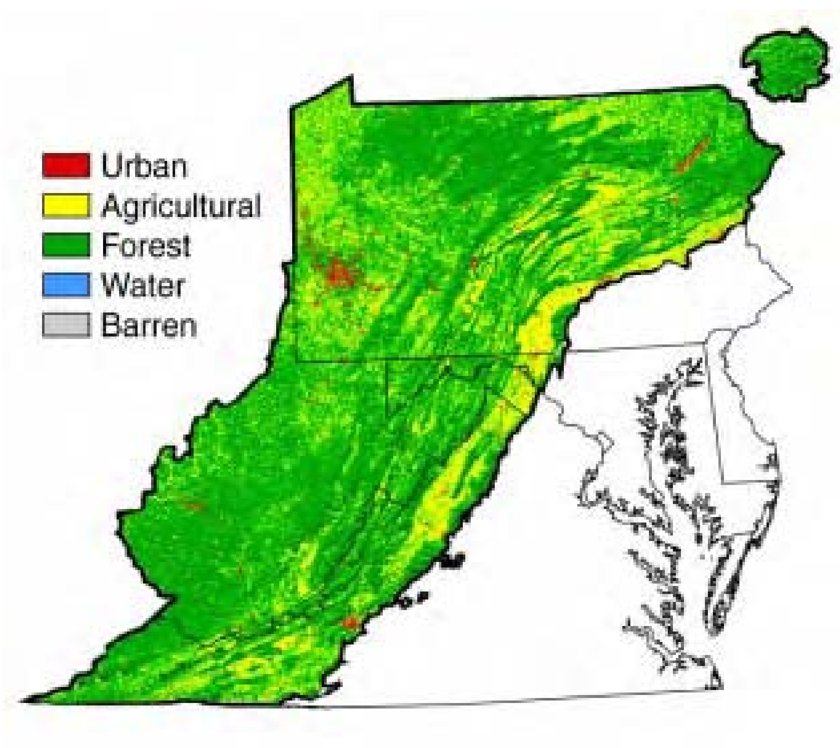


Figure 10. Land use classified from satellite imagery showing the complex mosaic of ecological systems in the Highlands.

Human activities have the potential to alter stream quality and affect the biota that lives in these streams. The characteristics or stressors in Highland streams and their watersheds included in this report are:

- Stream acidification,
- Nutrient runoff,
- Habitat alteration,
- Fish tissue contamination,
- Watershed disturbance, and
- Non-native fish introductions.

A brief description of each stressor is provided, followed by results. Where standards for the individual stressors are generally accepted, they were used to separate streams (or watersheds) into good, fair and poor quality classes. Where such standards do not already exist, we summarize the results using a scale that we believe is a defensible interpretation of information for that stressor. At the end of this section, the stressors are compared or ranked against one another so that the reader can develop some appreciation for differences and similarities in the extent and distribution of these stressors. This "comparative" or "relative" ranking simply compares the length of stream resource in poor quality for that stressor.

ACIDIFICATION OF STREAMS

Streams can become acidic through the effects of **acid deposition** (deposition of nitrogen and sulfur compounds produced by burning fossil fuels) or when water percolates through mines and mine tailings (mine drainage) (Figure 11). The Highland region is unusual because it receives some of the highest rates of acid rain in the U.S., has geology that makes large areas within the region susceptible to acidification, and has a high incidence of coal mining. Mountainous areas have shale and hard, igneous rocks that don't neutralize acids very well while some of the valleys have limestone, which does neutralize acids (see box on acid rain and mine drainage). Evaluations of stream chemistry (e.g., acid neutralizing capacity [ANC, in units of μeq/L], is a measure of the stream's ability to neutralize acids and **buffer** or prevent large pH changes) allow us to determine if streams are acidic (ANC<0) and whether the acidity is due to acid rain or to mine drainage (see text box on next page).

Streams may be acidic throughout the year (chronically acidic) or only for short periods when flows are high such as during storm events (episodically acidic). Because Highland streams were sampled during spring **base flow**, and not during storms, the data are best suited to estimating chronic acidity. Across the Highlands as a whole, less than 4% of the total stream length was chronically acidic (ANC<0) due to acid rain. How would this number

Photo by Alan Herlihy

Figure 11. Both acid rain and mine drainage can make a stream acidic, but mine drainage can contribute sediment and metals that further degrade streams downstream.

Acid Rain vs Mine Drainage

What is acidity? The acidity of a substance is measured using a pH scale that ranges from 0 (very acidic) to 14 (very alkaline). A value of 7 is considered neutral, and each number on either side is logarithmically more acidic or alkaline (for example, pH 6 is ten times more acidic than a pH of 7, and pH 5 is one hundred times more acidic than pH 7).

"Normal rain", measured at pH 5.6, is now rare for most of North America. Today the rain over the Mid-Atlantic is often over 100 times more acidic than "normal".

How does acidity effect stream biota? At a 6.5 reading on the pH scale, large fish begin to die. At 5.0 all zooplankton disappear, at 3.0 all fish disappear, and at 2.0 all insects disappear.

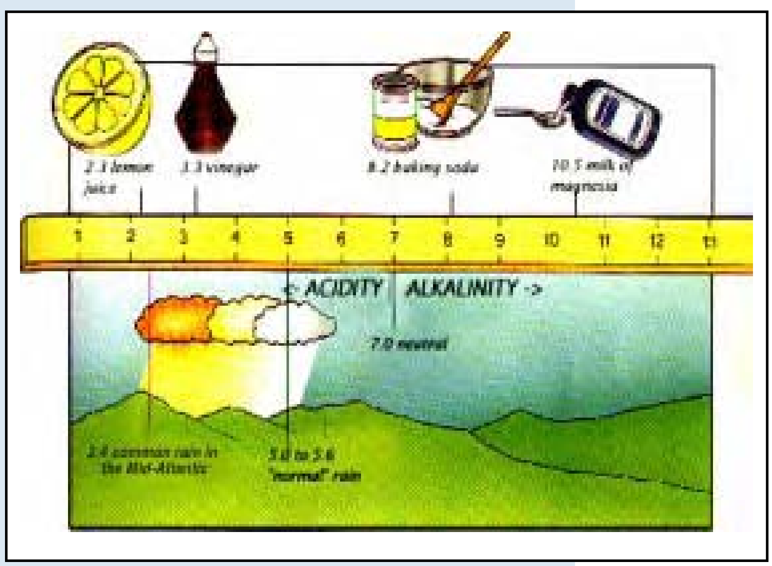
What is acid neutralizing capacity (ANC)? ANC is a measure of the capacity of dissolved constituents in the water to react with and neutralize acids. ANC is used as an index of sensitivity of streams to acidification. The higher the ANC, the more acid a stream can assimilate before experiencing a decrease in pH. When ANC approaches zero, the stream loses the capacity to buffer acid.

What is acid rain? Acid rain is rain that is more acidic than normal. The smoke and fumes from burning fossil fuels rise into the atmosphere and combine with the moisture in the air to form acid rain. Acid rain usually forms high in the clouds where sulfur dioxide and nitrogen oxides react with water, oxygen, and oxidants. This forms a mild solution of sulfuric acid and nitric acid. Rainwater, snow, fog, and other forms of precipitation containing those mild solutions of sulfuric and nitric acids fall to the earth as acid rain.

Acid rain may affect the soils, vegetation and water throughout a watershed. Controlling acid rain requires the regulation of sources often hundreds of miles away from the affected stream.

What is Acid Mine Drainage? Mine drainage is metal-rich water formed from chemical reaction between water and rocks containing sulfur-bearing minerals. The runoff formed is acidic and frequently comes from areas where ore- or coal mining activities have exposed rocks containing pyrite - a sulfur bearing mineral. This produces sulfuric acid and releases a number of metals such as iron, aluminum and manganese into streams.

Mines, especially when they occur near streams, usually have drainage that goes directly into the stream, contributing sediment, toxic metals, and acids. Treating mine drainage, often by constructing catchment basins below the mines, must be done at a local scale.



change if we considered both chronic and episodic acidity? The National Acid Precipitation Assessment Program (NAPAP) concluded in 1990 that streams with ANC values lower than 50 μeq/L are susceptible to episodic acidification. These streams may experience fish kills and changes to their insect communities during short-term pulses of acid rain runoff. When both chronic and episodic acidity are considered, about 11% of the total stream length in the Highlands would be considered to be affected by acid rain (Figure 12).

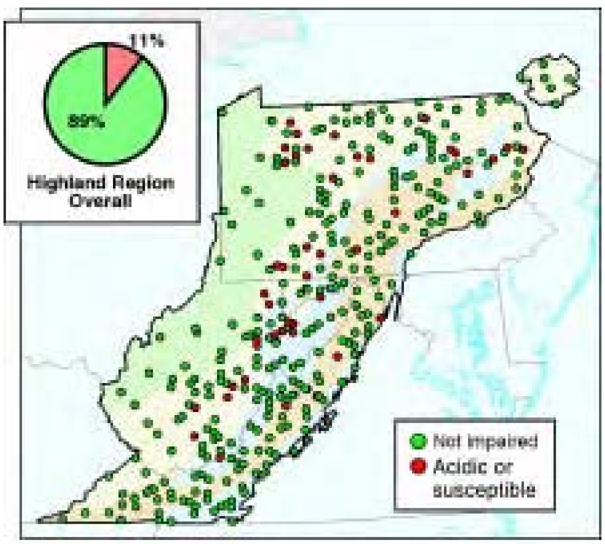


Figure 12. Proportion of stream miles that are acidic or susceptible to acid rain. Note some areas are more susceptible to acid rain because of low buffering capacity in the soils and bedrock.

Streams that are acidic due to mine drainage are much less common in the Highlands than streams acidified by acid rain. But mine drainage effects extend far beyond acidification, including downstream sedimentation and toxic metal contamination (metals reside primarily in bottom sediments in non-acidic streams).

These less well-known stresses can have pronounced effects on bottom-living organisms. While about 1% of stream miles in the Highlands are acidic because of mine drainage, 14% of the stream length is non-acidic, but degraded by mine drainage (Figure 13).

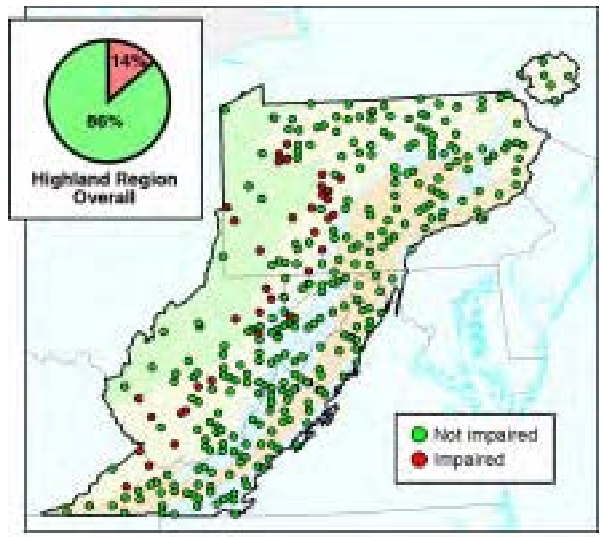


Figure 13. Proportion of stream miles that are affected by mine drainage. Coal is found in some Appalachian areas.

Nutrient Runoff

The introduction of excessive nutrients into streams can increase algal growth. If it becomes extensive, algal growth can deplete the oxygen in the water, choke out other forms of biota, and significantly alter the animal communities present. The increase in nutrients typically can be seen as higher concentrations of phosphorus, and the dominant sources are usually municipal/industrial discharges and runoff from agricultural fields (Figure 14). In general, phosphorus concentrations are low in

Chronic problems with acid rain and mine drainage still persist in Highland streams.

Highland streams, with about 90% of the stream length having concentrations less than 50 parts per billion (**ppb**) (Figure 15). Only 5% of the stream miles have total phosphorus concentrations that are considered high (greater than the EPA guideline of 100 ppb).

Photo courtesy of EMAP

Figure 14. Nutrient enrichment to streams can come from animal wastes such as livestock (cattle, hogs, and chickens); agricultural fertilizer applications to fields; and municipal and industrial waste treatment discharges.

Nitrogen is another nutrient that can stimulate plant growth, especially in the presence of high phosphorus concentrations. Like phosphorus, nitrogen is commonly found in agricultural fertilizers, but may also originate from acid rain (nitrogen deposition) and sewage discharges. There are no nitrogen guidelines for streams as there are for phosphorus, although EPA is currently developing new criteria for both nutrients. However, the ratio between nitrogen and phosphorus can serve as an indicator for when aquatic plants grow near their optimum rate. For the purposes of this assessment, we set total nitrogen thresholds by multiplying the total phosphorus thresholds by a nitrogen: phosphorus ratio (15:1) typical of undisturbed sites. This gave us nitrogen thresholds of 750 (for the division between good and fair condition) and 1,500 ppb (for the division between fair and poor condition).

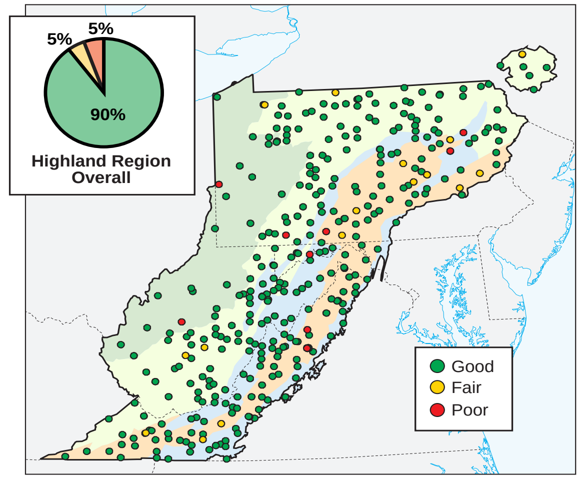


Figure 15. Total Phosphorus concentrations in most Highland streams are low (<50 ppb) or moderate (50-100 ppb).

Stream nutrient concentrations in the Highlands are in the good quality range

Based on these total nitrogen thresholds, 85% of the Highland stream miles were scored good, 10% fair, and 5% poor (Figure 16). Overall, nitrogen problems appear to be slightly greater in extent in the Highlands than do phosphorus problems, but the use of different nutrient criteria could alter this conclusion.

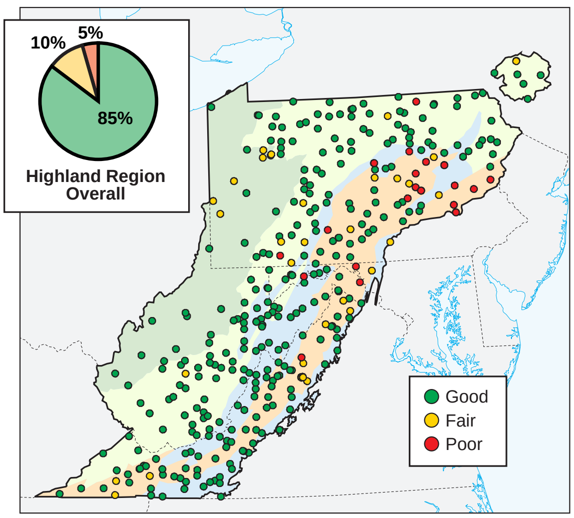


Figure 16. Total Nitrogen criteria for Highland streams were based on a ratio between total nitrogen and total phosphorus. 85% of stream miles were scored good compared to only 5% scored poor for nitrogen.

Physical Habitat Alteration

High quality physical habitat is an important and often overlooked ingredient for good stream condition. In the course of EMAP sampling, data were collected on many aspects of both riparian and instream habitat known to be important to biota. These data also can be used to diagnose the possible causes of habitat degradation. In this assessment, we focus on two characteristics of stream physical habitat (riparian habitat and sedimentation) that play perhaps the largest roles in establishing high quality streams for both fish and insects. Riparian (or streamside) vegetation shades streams, particularly small streams, maintaining cool water temperatures required by many biological organisms for growth and reproduction. It also strengthens and stabilizes stream banks and helps to prevent silt and associated contaminants from entering the stream. Riparian vegetation that washes into the stream can be a source of food for stream organisms. Instream large woody debris derived from riparian trees creates complex habitat and pools for stream fish and aquatic insects. Complex physical habitat within the stream itself provides areas where fish and aquatic insects can reproduce, feed, and hide from predators. Human beings alter stream physical habitat in a variety of ways: clearing vegetation from the banks and riparian areas, logging or farming up to the stream edge, building roads across streams, dredging and straightening the stream channel, and building dams or other diversion structures in the stream channel (Figure 17).

Habitat is the place or environment where a plant or animal naturally or normally grows and lives. Habitat combines food, water, shelter, and nesting or nursery areas. All plants and animals have specific habitat requirements that must be satisfied in order to live and thrive. Think of habitat as a "Life Support System."

In general, good stream habitats have the following basic characteristics: 1) wide, naturally vegetated riparian areas, 2) mean-

Photo courtesy of EMAP

Figure 17. Removing trees, shrubs and other tall grasses from stream banks contributes to poor riparian habitat.

dering channels, 3) a variety of substrate types (such as wood, roots, and rocks), and 4) a variety of water depths and water velocities.

The Index of Riparian Habitat Quality measures the condition of the riparian areas along the banks of the stream (characteristic #1, above). The metrics in the Index are: area covered by vegetation, types of vegetation (canopy, mid-layer and ground layer as well as coniferous and woody), and the intensity of human-generated activities (logging, agriculture, pipes, dams, etc.).

The Index of In-Stream Habitat measures the condition of the stream itself (characteristics #2-4, above). Some of the metrics in this Index are channel sinuosity (meandering vs straightness), amount of various types of substrates (sand, clay, rock, gravel, bedrock, wood or **detritus**), and water depth and velocity characteristics (dry channel, pools, riffles, falls).

Results of this assessment indicate that habitat degradation is a widespread problem in the Mid-Atlantic Highlands. Management actions that can be directed at this problem include protecting existing riparian forests, replanting protective vegetation along stream banks, and restoring streams to more natural flow regimes.

We incorporated aspects of riparian vegetation cover, riparian vegetation structural complexity, and the intensity of human disturbances into an index of Riparian Habitat Quality for use in this assessment. Based on historic literature and the judgement of experts, we assumed that

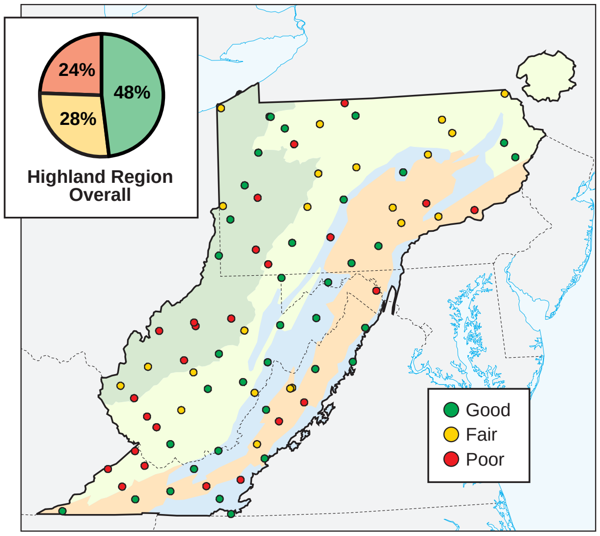


Figure 18. Riparian habitat quality for Highland streams. 24% of stream miles were in poor condition and 48% were in good condition for riparian habitat quality.

the pre-colonial reference condition for riparian vegetation in the Highlands is a multi-storied corridor of woody vegetation, with canopies that are closed (or nearly closed), and free of human disturbance. The resulting index varies from 0 to 1, with values less than 0.5 indicating streams with poor

Almost 25% of Highland stream miles have poor riparian habitat and excess channel sedimentation.

quality, values from 0.5 to 0.63 indicating streams with fair quality, and values greater than 0.63 suggesting streams with good riparian habitat.

In order to assess stream sedimentation, we compared measurements of the amount of fine sediments on the bottom of each stream with expectations based on each stream's ability to transport fine sediments downstream (a function of the slope, depth and complexity of the stream). When the amount of fine sediments exceeds expectations, it suggests that the supply of sediments from the watershed to the stream is greater than the stream can naturally process. For the purpose of this assessment, streams containing 90% or less of the predicted value of fine sediments were rated good. Those streams where the fine sediments ranged from 90% to 120% of the predicted value were rated fair, while those streams where fine sediments exceeded 120% of the predicted value were rated poor.

Physical habitat results for the Highlands as a whole indicate that 24% of the total stream length had poor riparian habitat, and 25% of the regional stream length had excess sedimentation (Figures 18 and 19). A higher proportion of stream miles have riparian zones with good habitat (48%) than have low sedimentation (35%) (Figures 18 and 19).

Fish Tissue Contamination

EPA has established criteria to protect both human beings and fish-eating wildlife from chemical contaminants that can be concentrated in fish tissue. During EMAP sampling in the Highlands, fish tissue samples were collected and analyzed for selected **organic** and metal **contaminants**. These contaminants included the potentially cancer-causing organic contaminants chlordane, dieldrin, heptachlor, and DDT, and the **toxic** metals arsenic and mercury. In the

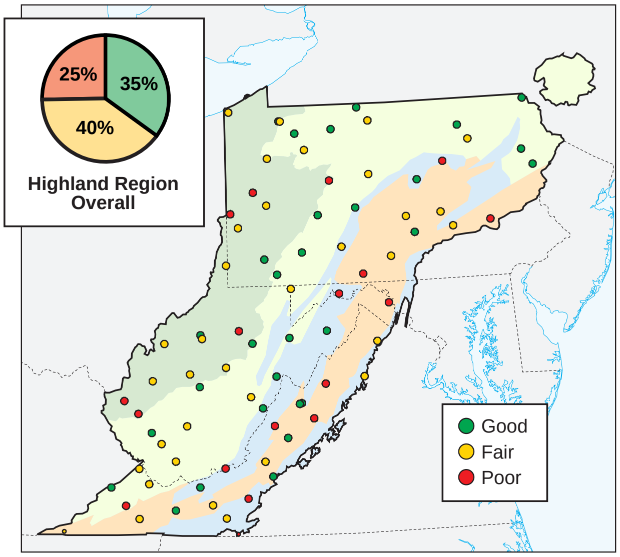


Figure 19. 25% of stream miles had poor quality while 35% had good instream habitat based on excess sedimentation.

case of the organic contaminants, fish tissue concentrations were compared to human health **carcinogenic** criteria. For the metals, we used **mammalian** wildlife protection criteria, which are lower than human health criteria. If fish tissue concentrations for any of the chemicals exceeded any of the criteria, the stream reach was classified as having contaminated fish tissue.

For the Highlands, 44% of the stream miles did not have sufficient quantities of fish tissue collected to do the analyses (Figure 20). The analyses require a relatively large amount of fish tissue, and not enough fish could be caught in many streams to get sufficient tissue.

About 10% of stream miles had fish contaminated by organic chemicals.

For streams with sufficient fish tissue for analysis, about 10% of the stream miles in the Highlands had at least one organic contaminant that exceeded human health criteria for carcinogens (Figure 20).

The only metal contaminant that exceeded wildlife criteria for fish-consuming mammals was mercury. Mercury concentrations in fish tissue exceeded the mammalian wildlife criteria in 4% of the Highland stream length (Figure 21).

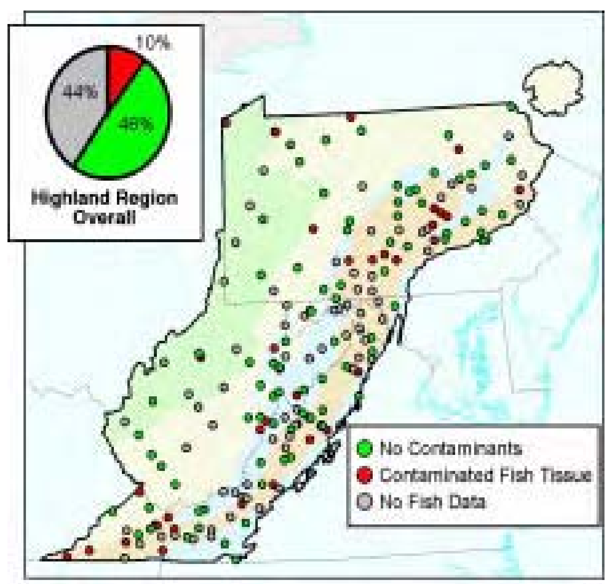


Figure 20. Fish tissue from about 10% of the stream miles in the Highlands had at least one organic contaminant that exceeded human health criteria. Note: No fish or insufficient fish tissue available for analysis occurred in 44% of the stream miles.

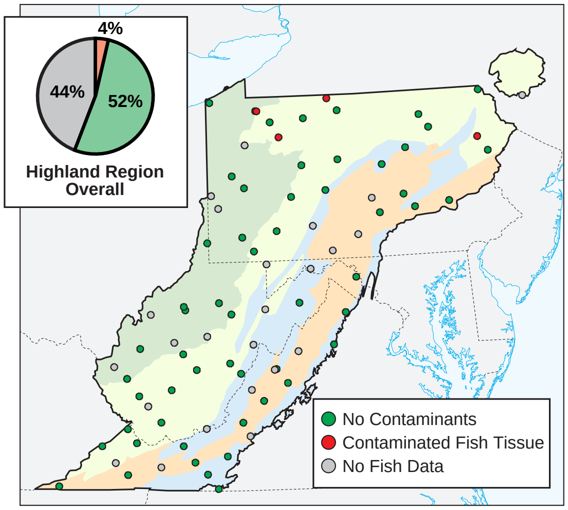


Figure 21. About 4% of the Highland stream miles had fish tissue mercury concentrations that exceeded mammalian wildlife criteria. Note that fish quantities were not sufficient for analysis in about 44% of the stream miles.

Watershed Disturbance

With increased population growth, a more mobile population, and the economic pressures of development, the effects of human activity also become more widespread. Streams reflect the quality of the watersheds they drain. To gauge the intensity of watershed disturbance in the Highlands, a watershed condition index was used to rank the disturbance in watersheds upstream from the EMAP stream sampling locations. The condition rank ranged from 1 for watersheds that were minimally disturbed (low road density, limited or no agriculture, no buildings, etc.) to 5 for watersheds that were heavily disturbed (crop production, urban development, mining, oil drilling, stream channelization, etc.). For the purposes of this assessment, we classified watersheds with condition scores of 1, 2 or 3 as minimally disturbed. Those with scores of 4 we classified as moderately disturbed, while a score of 5 indicated a heavily disturbed watershed.

For the entire Highlands, about 45% of stream miles were located in watersheds ranked in minimally disturbed condition, 30% in watersheds ranked as moderately disturbed, and 25% in watersheds ranked in heavily disturbed condition (Figure 22).

25% of Highland stream miles were in heavily disturbed watersheds.

The kinds of watershed disturbance that contribute to watershed condition scores also produce the "signals" that we associate

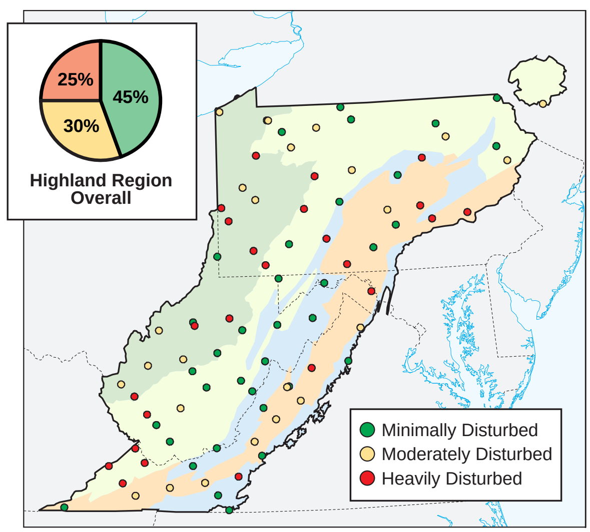


Figure 22. For the Highlands, 45% of the stream miles were in watersheds that were minimally disturbed, 30% moderately disturbed, and 25% were highly disturbed.

with the other stressors discussed in this section. A large number of mines, for example, will lead to a poor watershed condition score, and will produce the high sulfate concentrations that we use as an index of mine drainage effects. Because the watershed condition classes are, in this sense, more cumulative measures of stress than any of the other indicators discussed in this section, we do not include them in the relative stressor rankings discussed below.

Non-Native Fish: Stressor or Success Story?

"Great brown trout stream!" to some people means a successful fisheries management program. To others, it can mean the loss of biotic integrity and a threat to native fish species. In other words, some people consider fish stocking of non-native species to be a potential stressor in the stream. However, many states have specifically designated a stocked trout fishery as the aquatic life use for certain streams (see text box). In these streams, non-native fish, such as rainbow or brown trout, have been stocked and are managed by the states as a sport fishery. Non-native fish do not necessarily imply poor stream condition, but introduced species have been known to replace native fish by direct predation or by out-competing them for available habitat, food or both. In the Highlands, approximately 32% of the total stream length had at least one non-native fish species present (Figure 23). 17% of streams had no fish. Again, the lack of fish does not necessarily mean the streams are in poor

Definition of Designated Use

One of the goals of the 1972 Clean Water Act was to "restore and maintain the biological integrity of the Nation's waters." To achieve this goal, the Act calls for the formal designation of beneficial uses such as drinking water supply, primary contact recreation (e.g., swimming), and aquatic life support (e.g., fish) for each stream. Each designated use has a unique set of water quality requirements or criteria that must be met for the use to be attained. The familiar phrase "fishable and swimmable" is used to refer to the aquatic life support and primary contact recreation beneficial use categories. Some states have created subcategories of aquatic life use for specific types of fisheries, such as cold or warm water, to satisfy the public desires to fish for brown trout, rainbow trout, or smallmouth bass. Often these fish are not native to the stream or watershed, but rather have been artificially introduced.

The definition of biotic integrity used to develop the fish Index of Biotic Integrity reported in this assessment considers the stream to be of lower quality or condition if nonnative fish species are present in the stream because it is not the "natural" condition for the stream. The Clean Water Act does not define biotic integrity. This is an instance where the desire to maintain and protect the natural fisheries and the desire to designate a stream as an outstanding trout fishery can come in conflict. Designated stream uses currently take precedence over the ecological definition of biotic integrity.

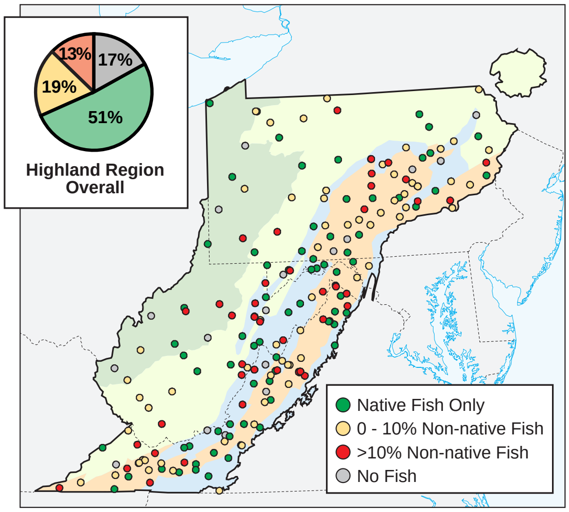


Figure 23. About 32% of the stream miles throughout the Highlands contain nonnative fish, including species stocked and managed for sport fisheries.

health. Some streams, particularly first-order streams, do not have fish but do have healthy aquatic insect communities.

Summary Ranking of Stressors

An important part of making future policy and management decisions is understanding the relative magnitude and extent of current stressors. Decision-makers may choose not to focus their efforts on the most common problems, but knowing which stressors are the most widespread should certainly be part of the information considered. In Figure 24, stressors were ranked according to the proportion of stream length impaired or in poor quality with regard to that particular indicator. The potential stressor that occurs in the highest proportion of streams is non-native fish (32% of all stream length in the Highlands). As discussed earlier in this report, many people do not consider introduced fish (often sport fish) to be a stressor; we list it here to highlight the broad extent of non-native fish in the Highlands, and leave it up to the reader to decide whether it

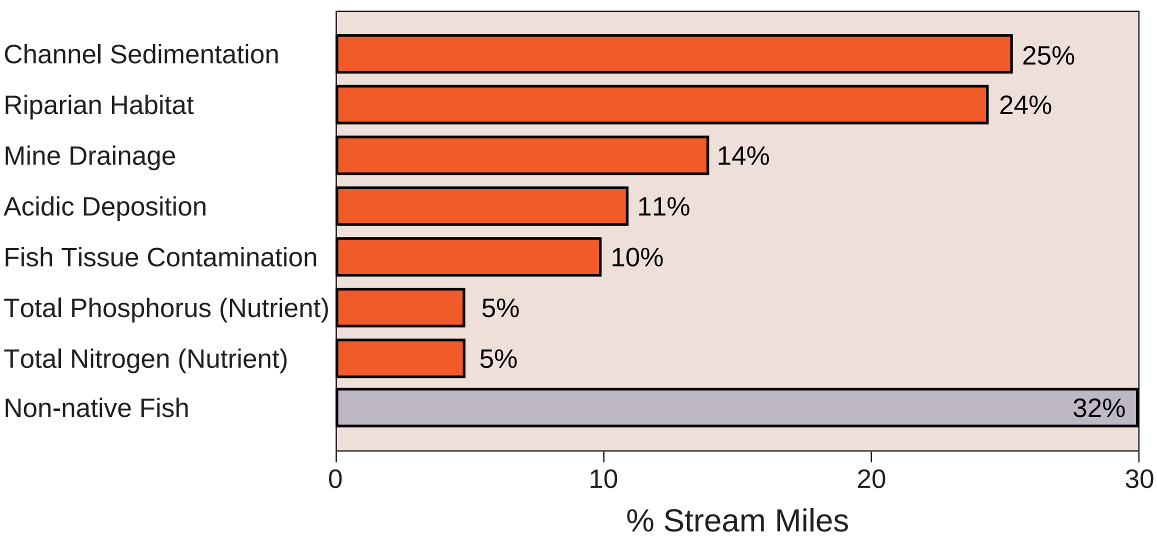


Figure 24. Overall ranking of stressors influencing the condition of Mid-Atlantic Highland streams.

should be considered a stressor in the same way as other stressors. The next most common stressors are both elements of stream physical habitat: channel sedimentation (25% of stream length) and riparian habitat disturbance (24% of stream miles). These stressors are followed by mine drainage (14%), acid rain (11%), fish tissue contamination (10%), and stream enrichment by total phosphorus (5%) and total nitrogen (5%) (Figure 24).

Habitat destruction is a major stressor in Highland streams.

ECOREGIONS, WATERSHEDS, AND STATES: ANOTHER PERSPECTIVE ON STREAM CONDITION

The statistical survey approach, measuring multiple indicators of the condition of Mid-Atlantic Highland streams, offers us a panoramic view of stream quality across the Highlands. By knowing first how many streams are in poor ecological condition, or are affected by particular stressors, we can begin to make informed decisions about what level of impairment we are willing to accept. In the Highlands as a whole, between 27 and 31% of the stream length is in poor ecological condition (depending on whether we use aquatic insect or fish data to make the assessment). The most significant stressors (e.g., those that are present in the largest proportion of stream length) are alterations to habitat (in-stream and riparian). While this assessment is informative, most management decisions aren't made at the scale or perspective of the Highlands as a whole.

An ecoregion perspective helps us to understand why streams respond to various human disturbances as they do and which management solutions might be applicable.

One of the major strengths of the sample survey design used in the Highlands is that it can be used and interpreted from various management perspectives or scales. We can use the same sort of approach (assessing first the ecological condition, then identifying the major stressors) to look at different geographic areas in the region such as **ecoregions**, large watersheds, or states. In this section, we present results for these different geographic areas, along with some ideas of how environmental managers and policy makers might choose to use these results.

ECOREGIONS

A different, but useful, management perspective can be gained by looking at stream quality by ecoregions (Figure 25). Ecological regions (or ecoregions) are areas that have similar soils, vegetation, climate, and physical geography. An ecoregion perspective highlights the differences, for example, between mountain areas with their steep slopes, shallow soils, and cool climate, and valley areas that are relatively flat, have deep soils, and warm temperatures.

Ecoregional differences play a major role in determining which streams have been affected by, or are susceptible to, different stressors: acid rain, mine drainage, and nutrient runoff. Management practices within an ecoregion typically are applicable for many streams with similar problems because the stream characteristics in the ecoregion are similar. Some problems or issues are more extensive in some ecoregions than others.

While looking at the Highlands as a whole can give us an idea which problems or stressors most require our attention, a spatial perspective can help focus management actions in the geographic areas that most need help. Focusing restoration efforts where problems are most extensive can make more effective use of limited resources.

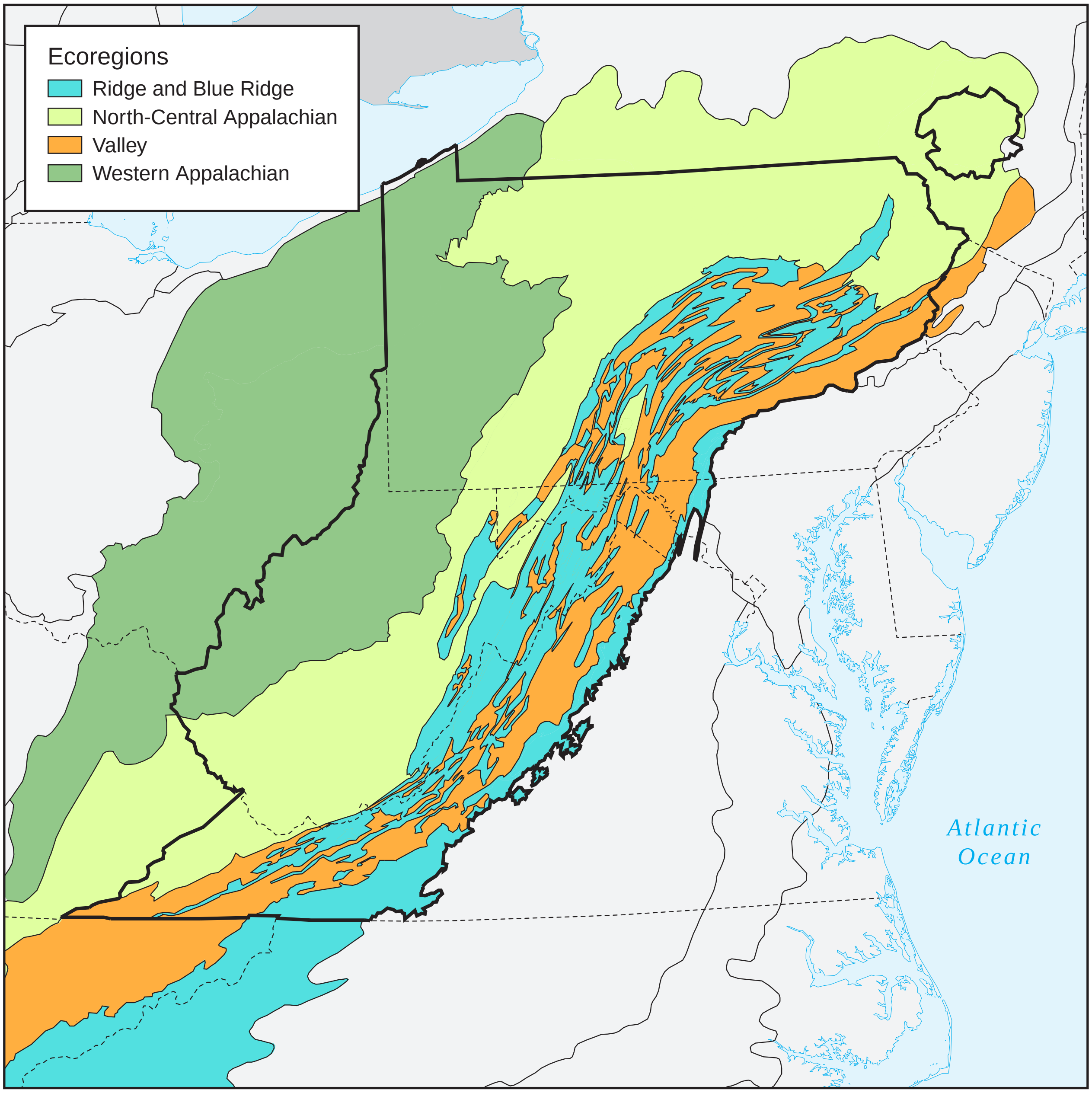


Figure 25. Ecoregions are areas with similar physical geography, soils, climate, and vegetation types. The Mid-Atlantic Highlands can be represented by four aggregated ecoregions. Ecoregions provide a useful perspective in viewing stream condition and characteristics (the Highlands area is enclosed by a bold black outline).

Western Appalachian Plateau

The Western Appalachian ecoregion runs from western Pennsylvania into western West Virginia (Figure 25). The hilly and wooded terrain of this ecoregion is less rugged and not as forested as the ecoregions to the east. Much of this region has been mined for bituminous coal. Once covered by a maple-beech-birch forest, this region is now largely in farms, many of which are dairy operations. This ecoregion is characterized by low rounded hills and extensive areas of wetlands. Based on the principles described above, the ecological condition of streams in the Western Appalachians would be considered the poorest of any ecoregion in the Highlands with respect to aquatic insects, and among the worst with respect to fish biotic integrity (Figures 26 and 27). 37% of stream miles in the Western Appalachians exhibited poor scores for the aquatic insect index, and only 2% of stream miles exhibited good scores. In the case of fish, 30% of stream miles had poor fish biotic integrity (35% of stream length could not be assessed for fish due to small stream size); only 3% of stream miles in the Western Appalachians exhibited good fish biotic integrity (Figure 26). Environmental managers in this ecoregion might well decide that these results are unacceptable, and begin looking for ways to improve stream quality. But where should they begin; which stressors should they target when they begin looking for restoration objectives?

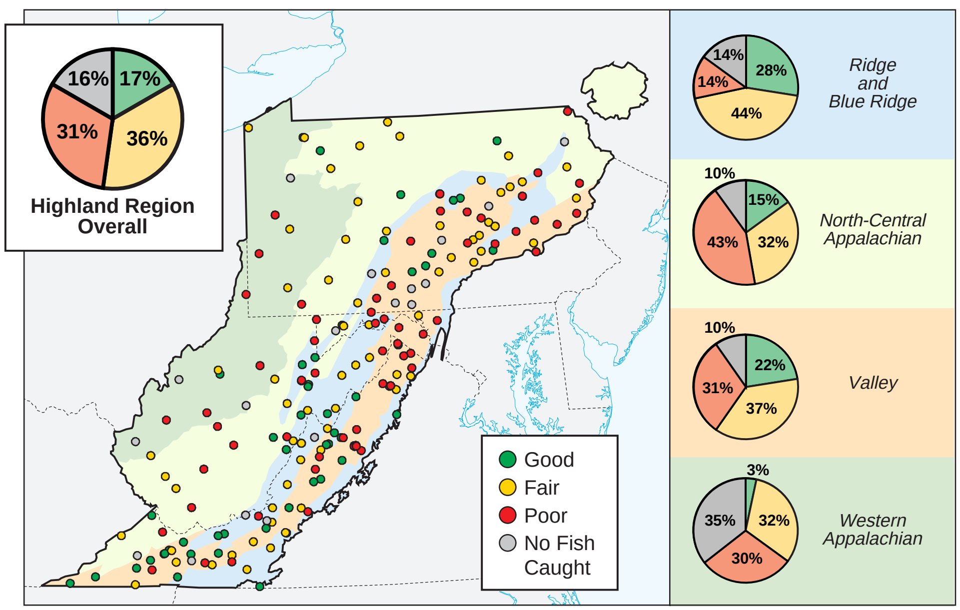


Figure 26. Fish IBI scores ranged from 14% in poor condition in the Ridge and Blue Ridge to 43% in poor condition in the North-Central Appalachian ecoregion.

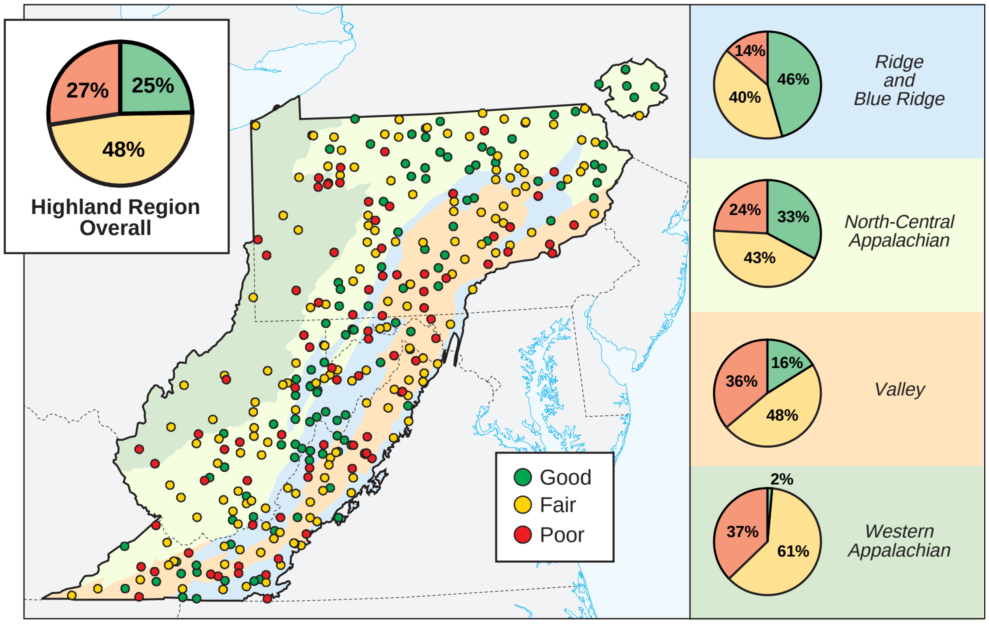


Figure 27. Aquatic insect index scores ranged from 14% in poor condition in the Ridge and Blue Ridge to 37% in poor condition in the Western Appalachian ecoregion.

Far and away the most common stressor in the Western Appalachians is sedimentation, with more than 38% of the stream length in the region exhibiting excessive fine sediments (Figure 28). Riparian habitat alteration (28% of stream length) and mine drainage (24% of stream length) are also common in the Western Appalachians. High phosphorus concentrations are also more common in this ecoregion (20% of stream length) than in any other. It is very likely that these high-ranking stressors are interrelated. While mining is most commonly thought of as having a chemical impact, it actually has a much larger effect on habitat, particularly on rates of sediment runoff to streams. Agricultural land use, which is common in the Western Appalachians, is also correlated with sediment problems; these are often associated with high phosphorus concentrations, because phosphorus attaches to fine soil particles and runs off into streams during the same high discharge storms that carry sediments into streams. It is very likely that managers who focused on measures to control runoff into streams from mines and agricultural fields could have a major impact on improving the ecological condition in this ecoregion.

On the positive side, fish tissue contamination is found in only 7% of the stream miles and the effects of acidic deposition and nitrogen runoff are essentially absent from the Western Appalachians (Figure 28). Non-native fish species are less common (19% of stream length) in the Western Appalachians than in any other Highland ecoregion.

North-Central Appalachian Plateau
The North-Central Appalachians in northern and central Pennsylvania and central West Virginia (Figure 25) are a vast elevated plateau of high hills, open valleys, and l ow mountains (Figure 28) with sandstone, siltstone, and shale geology and coal deposits. Much of the eastern part of the ecoregion is farmed and in pasture, with hay and grain for dairy cattle being the principal crops. There

In the North-Central Appalachians, (43% of stream miles in poor condition) based on fish IBI scores (Figure 26). The relatively good scores for aquatic insects in the North-Central Appalachians (24% of stream miles in poor condition; 33% in good condition, Figure 27) almost certainly result from the fact that sedimentation is much less prevalent in this ecoregion (only 10% of stream miles have excessive fine sediments) (Figure 28).

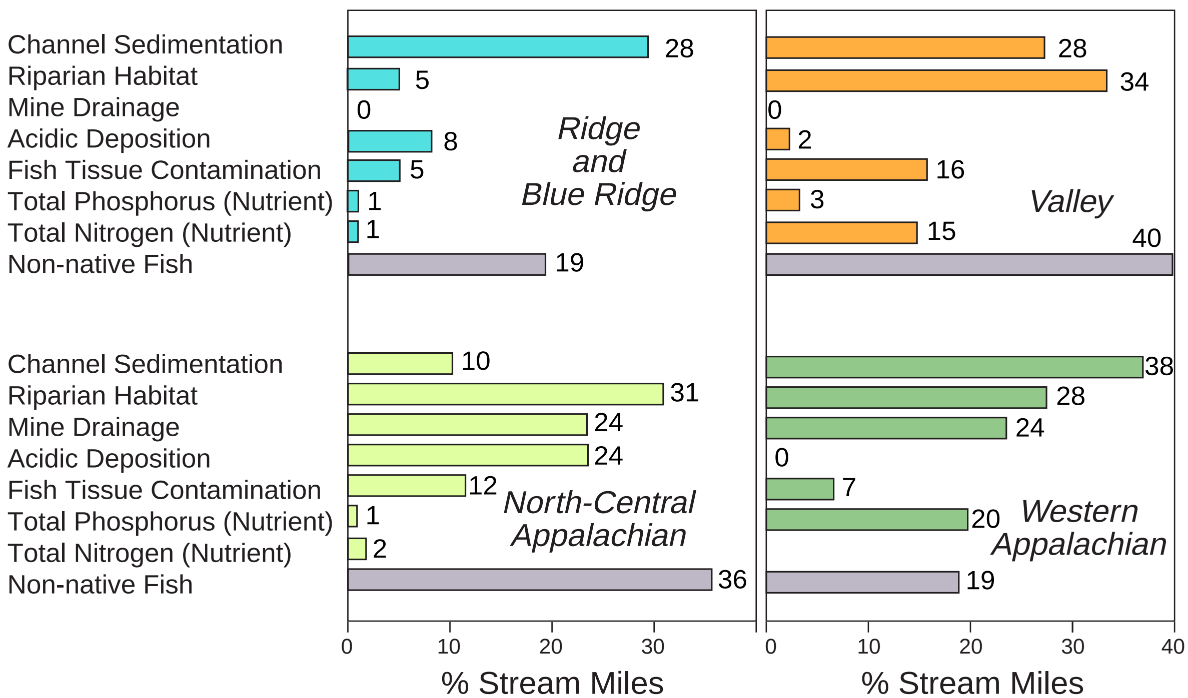


Figure 28. Ranking of stressors by ecoregion based on proportion of stream miles scored as impaired or with poor quality.

also are large areas in oak and northern hardwood forests. Land use activities are generally related to forestry and recreation, but some coal and gas extraction occurs in the west.

Many aquatic insect species, and other bottom-dwelling organisms, live in the gaps and spaces between boulders and gravels that disappear when sedimentation becomes a problem in streams.

The most common stressors in the North-Central Appalachians are riparian habitat alteration (31% of stream length), mine drainage and acidic deposition (both are found in 24% of stream miles in this ecoregion) (Figure 28). These are the problems that environmental managers might want to target for restoration efforts. Introduced fish species are also very common in the North-Central Appalachian Plateau, with 36% of stream miles having one or more non-native species. Nutrient runoff (<2% of stream length affected) is relatively unimportant in this largely non-agricultural ecoregion.

Valley

The Valley ecoregion extends from eastern Pennsylvania southwesterly through southwestern Virginia (Figure 25). The valleys generally are of two types, those underlain by limestone and those by shale. The nutrient rich limestone valleys contain productive agricultural land (Figure 29). By contrast, the shale valleys are generally less productive, more irregular, and have greater densities of streams. Most of the streams in the limestone valleys are colder and flow all year, whereas those in the shale valleys tend to lack flow in dry periods. Large poultry operations can be found in many parts of the valleys.

Photo by Jim Omernik

Figure 29. The Valley ecoregion extends from eastern Pennsylvania southwesterly through southwestern Virginia and contains productive agricultural land.

The proportion of stream length in poor ecological condition in the Valley based on aquatic insect scores (36%) was comparable to the poor stream condition measured in the Western Appalachians (Figure 27). Fish assemblage scores indicated about 31% of the stream length was in poor ecological condition in the Valley (Figure 26).

Over one-third of the stream miles (34%) had poor scores for riparian habitat alteration and 28% of the stream miles were scored poor for excess sedimentation (Figure 28). Physical habitat alteration, both riparian habitat and excess sedimentation, almost certainly contributed to the poor biological condition of the streams. The aquatic insects are particularly sensitive to excess sedimentation. Non-native fish species were found in about 40% of the stream miles in the Valley. Fish tissue contamination (16%) and total nitrogen (15%) each represent about half the number of stream miles associated with poor scores for physical habitat alteration. Agriculture and poultry operations might be contributing to the elevated nitrogen concentrations. Total phosphorus concentrations and acid rain are associated with less than 3% of the stream miles and mine drainage is not a problem in the Valleys. Managers might target physical habitat restoration in the Valley ecoregion to reduce this major environmental problem. Targeting physical habitat restoration should also help reduce nitrogen runoff.

Ridge and Blue Ridge

The Ridge and Blue Ridge ecoregion is a series of linear mountainous ridges with elevations from approximately 1,000 feet to 5,700 feet (Figure 25). This mostly forested ecoregion contains cool, clear streams with steep slopes which occur over mostly sandstone and shale bottoms. The ecoregion has no major urban areas and has a low population density. However, due in large part to the close proximity of metropolitan areas to the east (Philadelphia, Baltimore, Washington, D.C., Richmond) (see inside front cover), recreational development in the region has increased considerably in recent years.

Habitat destruction is a major stressor in every ecoregion.

Only the Ridge and Blue Ridge ecoregion has less than 25% of the stream miles in poor condition.

The Ridge and Blue-Ridge had the smallest number of stream miles with fish assemblage (14%) (Figure 26) and aquatic insect scores (14%) (Figure 27) indicating poor ecological condition. This region also had the greatest number of stream miles in good ecological condition based on fish IBI (28%) and aquatic insect (46%) scores. The Ridge and Blue-Ridge region is relatively undeveloped, with the predominant land use being forests.

Even in this region, however, about 19% of the stream miles have non-native species and 28% of the stream miles have excess sedimentation (Figure 28). The other stressors – poor riparian habitat, acidic deposition, fish tissue contamination and total phosphorus and total nitrogen concentrations - are each associated with less than 10% of the stream miles. Mine drainage is not a problem in the Ridge and Blue-Ridge region.

Common Themes

Physical habitat alteration - both riparian habitat and excess channel sedimentation - were prevalent and common in all the ecoregions. Targeting physical habitat restoration would reduce a major potential stressor throughout the Highlands and in all of the ecoregions.

WATERSHEDS

Watersheds are considered the primary management unit for many aquatic problems (Figure 30). Sediment transport and sedimentation, increased nutrient and contaminant loading, and similar problems are associated with water running off the land and washing sediment, nutrients and contaminants into the stream. Considering stream condition by watersheds can indicate which watersheds might be high priority candidates for management and restoration. Stressors can also be ranked by watersheds just as they were by ecoregions.

CHESAPEAKE WATERSHED

A major portion of the Chesapeake Bay watershed is contained in the Mid-Atlantic Highlands. Management practices in the Highlands portions of the Chesapeake watershed can help control problems in Chesapeake Bay. The Chesapeake Bay Program has recently implemented tributary strategies to improve conditions in the Bay. Both fish (Figure 31) and aquatic insect

Figure 30. Three watersheds or combined drainage basins can be assessed in the Mid-Atlantic Highlands. A watershed perspective is useful in viewing stream condition.

assemblages (Figure 32) indicated about 23 and 20%, respectively, of the stream miles in that portion of the Chesapeake Bay watershed in the Highlands were in poor ecological condition. The fish IBI scores for the Chesapeake watershed indicated that about 25% of the stream miles were in good condition, while the aquatic insect EPT scores indicated that about 32% of the stream miles were in good condition.

Channel sedimentation (25%) and riparian habitat alteration (12%) were the stressors that were associated with the highest proportion of stream miles in poor quality in the Chesapeake watershed (Figure 33). Other stressors of concern included acidic deposition (11%), total nitrogen (7%), and fish tissue contaminants (5%). Mine drainage and total phosphorus were not major stressors in the Chesapeake watershed. Non-native fish were found in 31% of the stream miles. The Chesapeake Bay Program has implemented a goal of 2,010 miles of riparian restoration by 2010. This goals applies to the entire Chesapeake watershed and only a portion of the restoration will occur in the Highlands region. Initial restoration effects are targeted toward planting trees, which should not only improve riparian habitat, but also help reduce excess channel sedimentation. These are two of the biggest problems in the Highland portion of the Chesapeake watershed.

Allegheny-Monongahela Watershed

The Allegheny and Monongahela Rivers join at Pittsburgh, PA to form the Ohio River

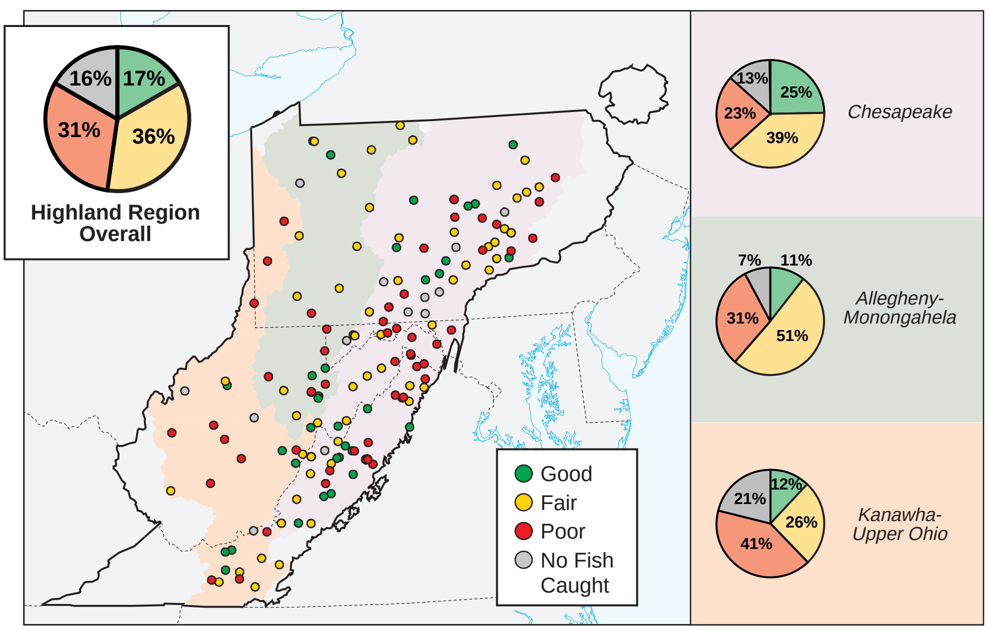


Figure 31. Fish IBI scores for streams in the Highland portions of three watersheds. Strong differences in the condition of fish assemblages exist among the three watersheds.

(Figure 30). This watershed is found in the middle area of the Highland region. Managing aquatic problems in the upper watersheds can help reduce problems in the Ohio River, the Mississippi River, and ultimately the Gulf of Mexico.

About 31% of the stream miles were scored in poor ecological condition using the fish IBI index (Figure 31) while about 22% of the stream miles were scored in poor condition using the aquatic insect index (Figure 32). The fish index indicated that only about 11% of the stream miles were in good condition while the aquatic insect index indicated that 27% of the stream miles were in good condition. Some of these differences are likely due to the stressors that are associated with the streams in the Allegheny-Monongahela watershed. Fish assemblages are typically more sensitive to the riparian habitat, acidic deposition, and mine drainage stressors.

Riparian habitat alteration (28%), acidic deposition (26%), mine drainage (20%), and fish tissue contamination (19%) were the major stressors associated with stream miles in the Allegheny-Monongahela watershed (Figure 33). All of these stressors were associated with at least 20% of the stream miles in this watershed. Non-native fish species were found in 46% of the stream miles in this watershed. Channel sedimentation (6%), total phosphorus (2%), and total nitrogen (2%) concentrations were not major stressors in this watershed. The fish index scores indicated a greater number of stream miles were in poor condition with fewer stream miles in good condition than

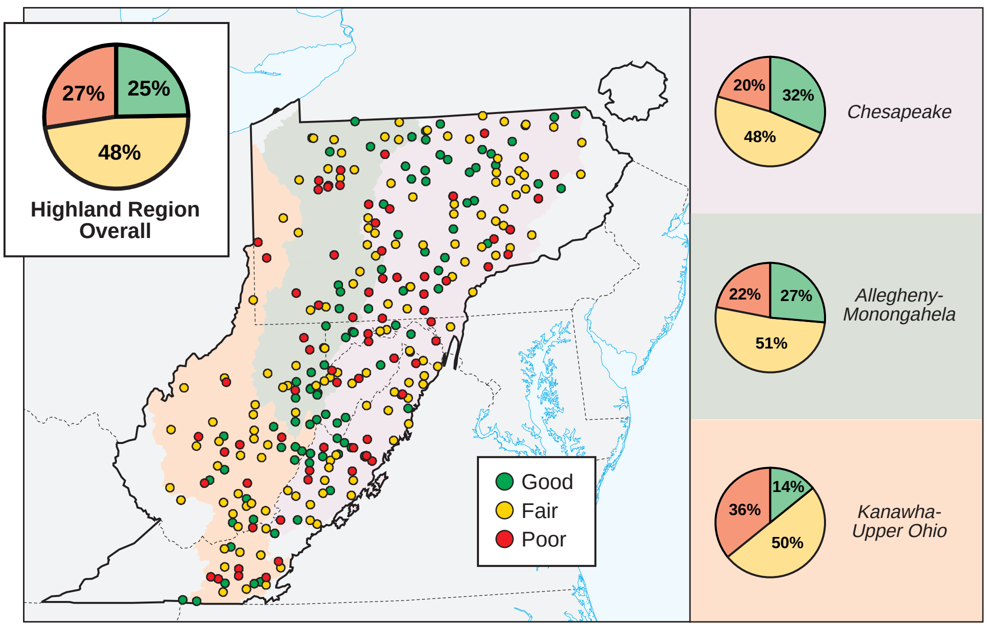


Figure 32. EPT scores for streams in three Highland watersheds.

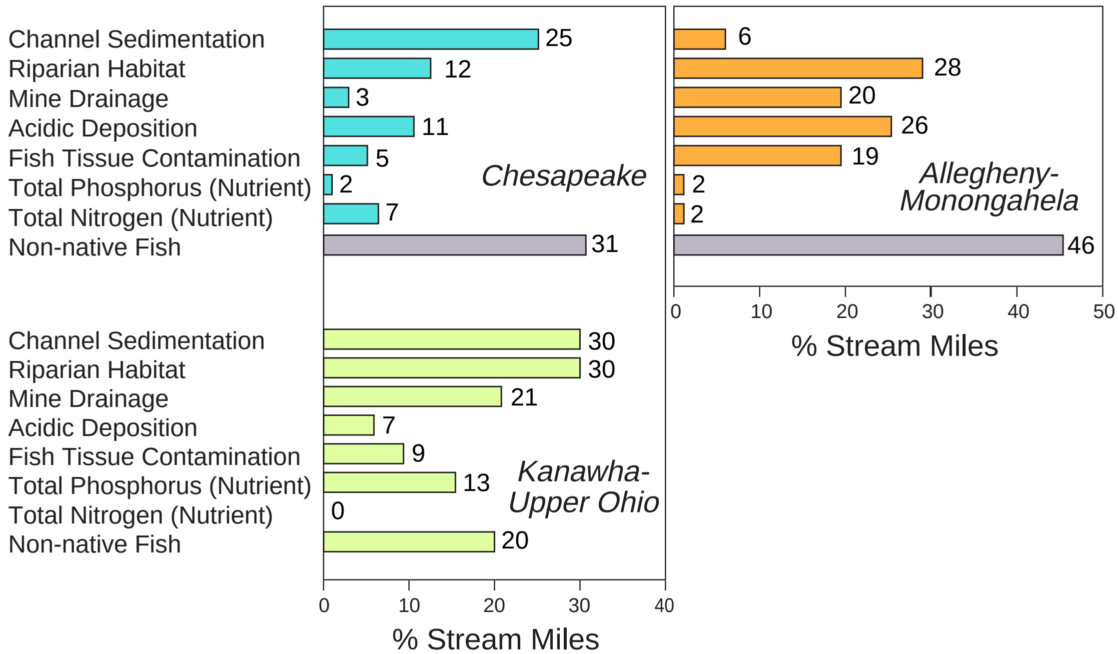


Figure 33. Ranking of stressors among streams in three Highland watersheds. While the general ranking of stressors is similar, there were differences among watersheds.

the aquatic insect scores. Using multiple indicators or indices provides a better picture of stream condition than any one single indicator or index.

Kanawha-Upper Ohio Watershed

The Kanawha-Upper Ohio watershed is located in the southern and western portion of the Highland region (Figure 30). About 21% of the stream miles in this watershed were scored in poor condition using the fish IBI (Figure 31) and about 36% of the stream miles were scored in poor condition using the aquatic insect index (Figure 32). The number of stream miles in good condition were scored similarly by the fish (12%) and aquatic insect indices (14%).

Channel sedimentation (30%) and riparian habitat alteration (30%) are the two stressors that were found in the greatest number of stream miles throughout the Kanawha-Upper Ohio watershed (Figure 33). These two stressors were followed by mine drainage (21%) and non-native fish (20%). Total phosphorus concentrations above the EPA guideline were associated with about 13% of the stream miles, the highest proportion found for any of the three watersheds. Fish tissue contamination was found in about 9% of the stream miles where there was sufficient fish tissue to measure contaminants. Acidic deposition was an issue in about 7% of the stream length and elevated total nitrogen concentrations were found in less than 1% of the stream miles in this watershed. The aquatic insect index is particularly sensitive to channel sedimentation, which likely explains why there were a greater proportion of stream miles scored in poor condition with this index. Again, this reinforces the importance of using multiple indicators or indices to determine stream condition.

> ***Stream miles in poor condition ranged from 23% in the Chesapeake watershed to 41% in the Kanawha-Upper Ohio watershed.***

Common Themes

Riparian habitat alteration was a high ranking potential stressor in each of the three watersheds. Channel sedimentation was a high ranking potential stressor in the Chesapeake and Kanawha-Upper Ohio watersheds, while mine drainage was a high ranking potential stressor in the Allegheny-Monongahela and Kanawha-Upper Ohio watersheds. Management practices should be targeted to these high ranking stressors in the various watersheds. Targeting channel sedimentation and riparian habitat should also reduce total nitrogen and total phosphorus concentrations. Targeting mine drainage also will reduce excess channel sedimentation. Stream restoration practices for these problems include re-establishing bank vegetation, putting riffles back in the stream channel, and adding boulders and tree trunks to stabilize the channel. Re-establishing vegetative buffer zones along the stream bank helps reduce sediment and nutrient loads to the streams.

States

Management at the state level is critical for effective environmental protection, management, and restoration. In many instances, the management units for the states also are ecoregions and watersheds. Because West Virginia is fully within the boundaries of the Highlands and most of Pennsylvania is located in the Highland region, the statistical survey design results are also applicable for these two states. Management insights can be gained by looking at the condition of streams, and the ranking of stressors in these two states.

Pennsylvania

The number of miles of stream scored in poor ecological condition was 27% using both the fish (Figure 34) and aquatic insect indices (Figure 35). The number of stream miles scored in good condition by the aquatic insect index was 25% compared with 14% of the stream miles scored in good condition by the fish IBI.

Riparian habitat alteration and channel sedimentation were associated with 21% and 19% of the stream miles, respectively, in Pennsylvania (Figure 36). Mine drainage, acidic deposition, and fish tissue contamination were also associated with about 15% of the stream miles. Nutrient concentrations of both total phosphorus and total nitrogen were stressors

> ***Habitat destruction was a major stressor in all watersheds.***

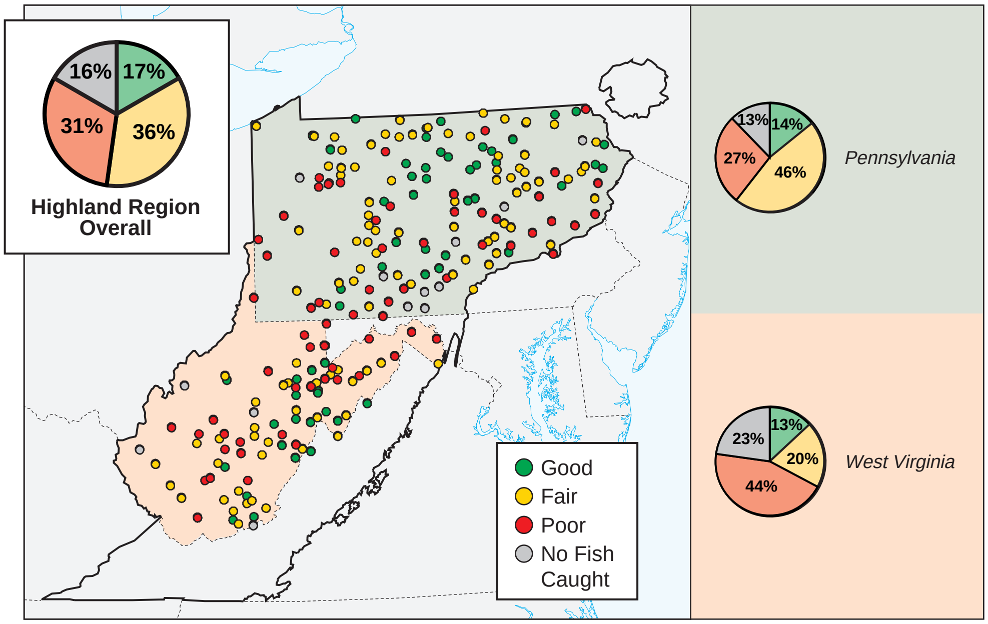


Figure 34. Comparison of Fish Index of Biotic Integrity scores between Pennsylvania and West Virginia showing proportion of stream miles in good, fair, and poor conditions based on a best attainable reference.

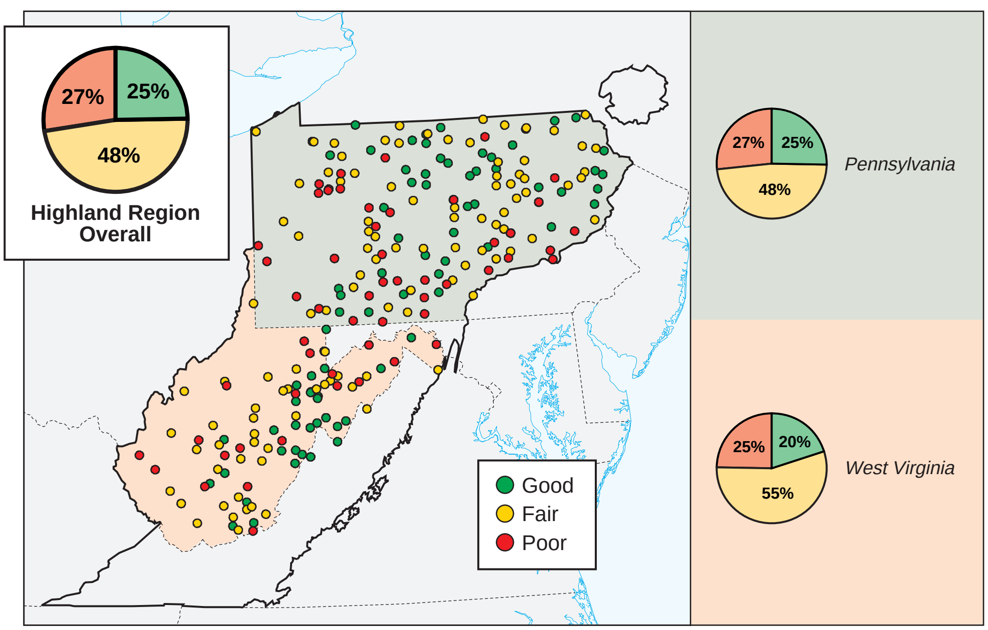


Figure 35. Comparison of aquatic insect scores for Pennsylvania and West Virginia streams.

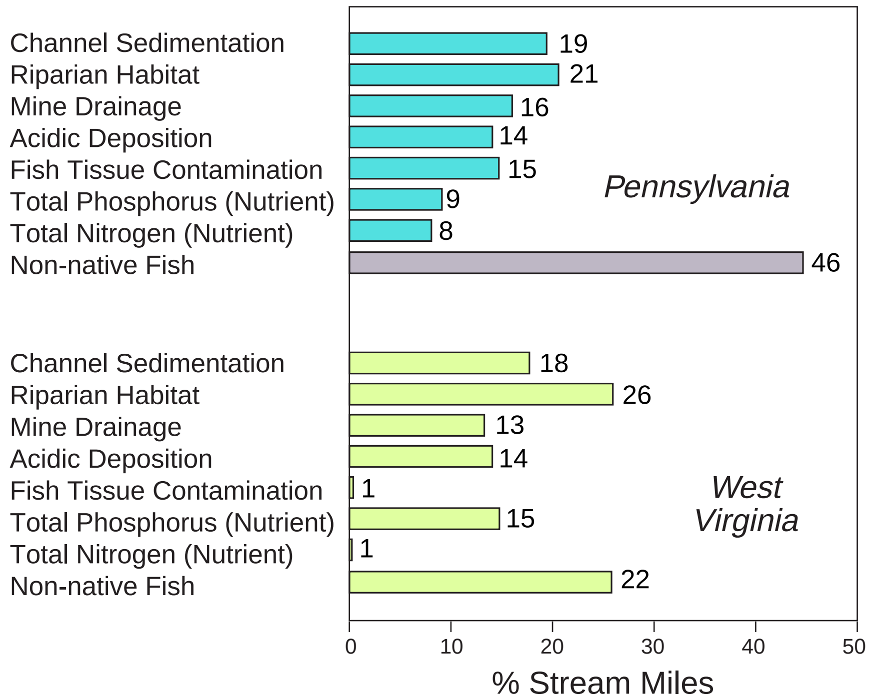


Figure 36. Comparison of stressors in streams between Pennsylvania and West Virginia. In general, the stressors in Highland streams in these two states were similar, except for total nitrogen enrichment and fish tissue contamination.

in about 10% of the stream miles. Pennsylvania has many stocked trout streams so non-native fish were found in 44% of the stream miles.

West Virginia

In West Virginia, 44% of the stream miles were scored in poor ecological condition using the fish IBI (Figure 34) compared with 25% of the stream miles scored in poor condition using the aquatic insect index (Figure 35). Similar differences were observed for the number of stream miles scored in good condition. The fish IBI scores indicated 13% of the stream miles were in good ecological condition compared with 20% scored in good condition using the aquatic insect index.

Physical habitat alteration – (26%) riparian habitat and excess channel sedimentation (18%) – were the two highest ranked stressors in West Virginia streams (Figure 36). Mine drainage and acidic deposition were each associated with about 14% of the stream miles. Total phosphorus concentrations rarely exceeded the EPA guidelines in West Virginia streams and fish tissue contamination and total nitrogen concentrations in the poor category were associated with 1% or less of the stream miles. Non-native fish species were found in 26% of the stream miles in West Virginia.

Common Themes

Physical habitat alteration (both excess channel sedimentation and riparian habitat) are major stressors in both states. Mine drainage and acidic deposition are also stressors that are common in both states, and are associated with similar numbers of stream miles. Management practices in both states might be targeted to these stressors.

Non-native fish species also were found in at least 25% of the stream miles in both states.

Habitat destruction is also a major stressor in both Pennsylvania and West Virginia.

Developing a Scorecard: Summarizing Stream Condition

The statistical survey approach, measuring multiple indicators of the ecological condition of Mid-Atlantic Highland streams, offers a panoramic view of stream quality across the Highlands. By knowing, first, how many streams are in poor ecological condition, and the ranking of the stressors, we can begin to make informed decisions about what levels of impairment we will tolerate and how to target management and restoration efforts to address those streams whose level of impairment is not acceptable. The following example illustrates how this information can be integrated across the Highlands, how tolerable and intolerable levels of impairment might be defined, how a score card can be developed, and how it might be used to target geographic areas for management.

For this exercise, let's suppose that if less than 10% of the streams are scored in poor ecological condition we can tolerate the situation. We don't desire impaired streams, but we can tolerate it if less than 10% of the streams are in poor ecological condition. However, if the proportion of stream miles scored in poor condition is between 10 and 25%, a yellow flag is raised. This yellow flag indicates that additional monitoring of change over time is needed to determine if this percentage is increasing or decreasing. If it is increasing, decision makers, managers and the public need to evaluate this situation and decide if this represents a high priority for management. If it is decreasing, current management practices should be continued.

If more than one-quarter – 25% – of the stream miles are in poor ecological condition based on any biological index, regional stream quality would be considered unacceptable and management or policy actions are needed now. (NOTE: only biological indicators or indices are used to determine stream ecological condition.)

Similar thresholds can be used to rank the stressors (e.g., less than 10% of the stream miles scored poor are tolerable, between 10 and 25% of the stream miles raises a warning flag, and over 25% of the stream miles might require a management action if the potential stressor is associated with poor ecological condition). The only exception to these thresholds is for fish tissue contaminants, which have both human health and ecological health implications. For fish tissue contaminants, let's assume that less than 2% of the stream miles with fish tissue contaminants is tolerable, between 2 and 10% is a warning zone, and that greater than 10% of the stream miles with fish tissue contaminants is intolerable. We can use this information to rank stressors similar to the ranking of stream ecological condition.

Overall, Highland stream condition is poor.

By using these thresholds, we can prepare a color-coded table or scorecard (Table 3) – green for tolerable, yellow for warning, and red for unacceptable – that pulls all this information

Scorecards integrate stream condition and stressors.

together. In addition, we can summarize the information in the same table for different geographic areas and management perspectives – i.e., the entire Highland region, ecoregions, watersheds or states.

Based on the score card in Table 3, the overall ecological condition of the region is poor, for both biological indices. In fact, the only management area in which ecological condition is not poor is the Ridge & Blue Ridge ecoregion, where ecological condition is fair.

Physical habitat destruction is the greatest potential stressor.

Physical habitat alteration, overall, represents that greatest potential stressor in almost all the geographic areas as well as across the Highland region as a whole. The other stressors, in general, can be targeted in specific geographic management areas, but are not wide-spread across the entire Highland. Some chronic problems such as mine drainage and acid rain still persist. However, nutrient problems are not as common in Highland streams as in other regions of the country.

Non-native fish species might be the greatest potential stressor to the Highlands region overall, or it might represent a success story for trout, smallmouth bass, or similar fisheries management programs. There are societal arguments on both sides of this issue – loss of biological integrity versus improved recreational opportunities. This will continue to be, and should be, a topic of public discussion.

Score cards such as Table 3 can be used to target geographic areas with high priority environmental problems for implementing management practices. A scorecard helps pull information together and display it so that informed decisions can be made on where to target geographic areas and how to prioritize management practices.

Table 3. Scorecard for Mid-Atlantic Highland Streams.

Condition & Stressor Ranking	Highland Region	Ecoregions				Watersheds			States	
		Western Appalachian	NC-Appalachian	Valley	Ridge & Blue Ridge	Chesapeake	Allegheny-Monongahela	Kanawha Upper Ohio	PA	WV
Ecological Conditions										
- Fish	31	30	43	31	14	23	31	41	27	44
- Aquatic Insects	27	37	24	36	14	20	22	36	27	25
Potential Stressors										
Habitat										
- Channel Sedimentation	25	38	10	28	28	25	6	30	19	18
- Riparian Streambank	24	28	31	34	5	12	28	30	21	26
Water Quality										
- Mine Drainage	14	24	24	0	0	3	20	21	16	13
- Acid Rain	11	0	24	2	8	11	26	7	14	14
- Total Phosphorus	6	20	1	3	1	2	2	13	9	5
- Total Nitrogen	4	0	2	15	1	7	2	0	8	1
Fish Contaminants										
- Carcinogens	10	7	12	16	5	5	19	9	15	1
- Mercury	4	6	8	0	0	4	15	0	9	0
Biological										
- Non-Native Species	32	19	36	40	19	31	46	20	44	26

Note: Green = <10% of stream miles ranked as poor. Yellow = 10 to 25% of stream miles ranked as poor. Red = >25% of stream miles ranked as poor. Nonnative species are managed in some streams so they are ranked as neutral.

*Fish Contaminants

Green = <5% of stream miles with any contaminant in fish tissue.

Yellow = 5 to 10% of stream miles with an contaminant in fish tissue.

Red = >10% of stream miles with any contaminant in fish tissue.

Management Implications

Some of the management implications from assessing the ecological condition of Highland streams are:

- ☞ **You can't play the game without a scorecard.** A score card can help pull all the information together and indicate environmental problems and target areas for management.

- ☞ **You can't develop a scorecard using existing monitoring networks.** Statistical stream survey designs are a cost-effective and efficient way to get information on the condition of streams in the Mid-Atlantic region. Survey designs complement, not replace, existing monitoring networks.

- ☞ **A single indicator only tells part of the story.** Multiple indicators and indices are needed both to determine stream ecological condition and to identify stressors affecting stream condition. Biological indicators or indices should be used to assess ecological condition.

- ☞ **Chemical indicators don't tell the whole story.** Biological indicators and indices integrate across physical and chemical indicators.

- ☞ **Just one management perspective is not enough.** Different management perspectives - region-wide, ecoregion, watershed, state levels - are important in determining where the high-priority environmental problems are and where to target management efforts.

- ☞ **You can't evaluate the success of management actions without repeated monitoring.** Monitoring the change in stream condition after management actions have been taken is the only approach for evaluating the success of these actions. Unfortunately, monitoring networks are generally cut-back or discontinued when budgets get tight.

Where Do We Go From Here?

There has been progress since the passage of the Clean Water Act in 1972. Point source discharges are now permitted, best management practices are being implemented to control nonpoint source runoff, and restoration activities are underway throughout the Highlands. Yet, over one-quarter of the stream miles in the Highlands are in poor condition. We still have a ways to go.

Habitat degradation is occurring across the Highlands and is affecting the condition and quality of our streams. Conversion of forest land into other land uses (e.g., agriculture, housing developments, commercial developments) and fragmentation of the forests (road building, parceling areas into lots) represents one of the greatest sources of habitat degradation. *"Smart growth"* is no longer just a catchy phrase; it is a necessity if we are to protect and improve stream condition throughout the region. Best management practices must accompany these conversions for all types of land use.

Based on the results of this assessment, targeted management practices can be identified for different ecoregions, watersheds, and states. This will include protecting streams in some areas such as the Ridge and Blue Ridge ecoregion, managing stream corridors in areas such as the Chesapeake watershed, and restoring streams in West Virginia that have been degraded by mine drainage.

To be able to assess future progress, we must continue to monitor stream condition. Monitoring is typically one of the first activities to be cut when budgets get tight. Yet, monitoring is the only way we can assess our progress and determine if our management practices are effective. The statistical survey approach used in this study is an innovative, cost-effective way of complementing other monitoring networks and provide the kind of information we need to determine if we are making a difference.

Together, we can make a difference in protecting, managing, and restoring Highland streams, but it will take a team effort. Just as we worked together with partners from the states, other agencies, universities and the private sector to conduct this assessment, so do we need to continue this partnership to improve stream conditions in the future. Coming together is a beginning; staying together is progress; working together is success. We can, if we chose, be successful in improving stream conditions throughout the Mid-Atlantic region - we simply need the resolve to get it done.

Together we can make a difference, but we must work together.

Appendix A: Additional Readings

Technical Journal Articles in Support of the Highlands stream report:

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Landers, D.H., R.M. Hughes, S.G. Paulsen, D.P. Larsen, and J.M. Omernik. (1998). How can regionalization and survey sampling make limnological research more relevant? *Verhandlungen Internationale Vereinigung fur Theoretische und Angewandte Limnologie* 26: 2428-2436.

Larsen, D.P., and Herlihy, A.T. (1998). "The dilemma of sampling streams for macroinvertebrate richness." *Journal of the North American Benthological Society*, 17, 359-366.

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US Environmental Protection Agency. (1998). Condition of the Mid-Atlantic Estuaries. US Environmental Protection Agency, Office of Research and Development, Washington, DC 20460. *EPA/600/R-98/147.*

MAIA Web-based Documents:

US Environmental Protection Agency. (2000). Mid-Atlantic Highlands Streams Assessment: Technical Support Document US Environmental Protection Agency, Office of Research and Development and Region 3, Mid-Atlantic Integrated Assessment Program, Ft. Meade, MD 20755.

Other EPA Reports:

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Additional Mid-Atlantic Highlands Reading:

Ator, S.W., and Ferrari, M.J. (1997). *Nitrate and selected pesticides in ground water of the Mid-Atlantic region*, U.S. Geological Survey.

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Websites:

MAIA - www.epa.gov/maia
EMAP - www.epa.gov/emap

Appendix B: Stream Population Estimates

Appendix B: Table B1. Percent of stream miles in good condition or affected by potential stressors for the Mid-Atlantic Highlands, four Highland ecoregions, three watersheds, and two states.

	MID-ATLANTIC REGION	ECOREGION				WATERSHED			STATE	
Constituents		North-Central Appalachians	Ridge & Blue Ridge	Valley	Western Appalachians	Chesapeake	Allegheny-Monongahela	Kanawha-Upper Ohio	Pennsylvania	West Virginia
Fish IBI[1]	17	15	28	23	4	25	11	12	14	13
EPT Index[1]	25	33	46	16	3	32	27	14	25	20
Nonnative Fish[2]	48	52	61	52	37	59	42	57	46	58
Fish Tissue Contamination[3]										
- Carcinogens	46	66	36	37	41	47	59	48	53	56
- Mercury	52	70	41	53	41	48	64	57	59	57
Mine Drainage[4]	86	76	100	100	76	97	81	79	84	87
Acidic Deposition[4]	89	76	92	98	100	89	74	94	86	86
Total Nitrogen[6]	85	93	98	70	68	85	91	83	73	98
Total Phosphorus[5]	90	97	95	89	74	95	89	83	84	93
Riparian Habitat	48	40	92	19	35	52	58	39	46	41
Instream Habitat	35	50	47	27	21	31	48	29	33	43
Watershed Condition[1]	45	52	77	18	2	45	47	48	35	64

1 % stream miles in good condition
2 % stream miles without nonnative fish
3 % stream miles without at least one constituent above human health carcinogen criteria or above mammalian mercury criteria
4 % stream miles not affected
5 % stream miles with TP<50 ug/L EPA guideline
6 % stream miles with TN < 1,300 ug/L based on EPA TP guideline

Appendix B: Table B2. Percent of stream miles in fair condition or affected by potential stressors for the Mid-Atlantic Highlands, four Highland ecoregions, three watersheds, and two states.

	MID-ATLANTIC REGION	ECOREGION				WATERSHED			STATE	
Constituents		North-Central Appalachians	Ridge & Blue Ridge	Valley	Western Appalachians	Chesapeake	Allegheny-Monongahela	Kanawha-Upper Ohio	Pennsylvania	West Virginia
Fish IBI[1]	36	32	44	37	32	39	51	26	46	20
EPT Index[1]	48	43	41	48	61	48	52	50	48	55
Nonnative Fish										
Fish Tissue Contamination										
- Carcinogens										
- Mercury										
Mine Drainage										
Acidic Deposition										
Total Nitrogen[2]	10	5	<1	15	24	8	7	17	19	2
Total Phosphorus[3]	5	2	4	8	6	4	9	4	8	2
Riparian Habitat[1]	28	28	3	48	37	36	14	31	34	33
Instream Habitat[1]	40	40	26	45	51	44	46	41	48	39
Watershed Condition[1]	30	21	13	48	4	35	17	30	27	28

1 % stream miles in fair condition
2 % stream miles with TN > 1,300 ug/L but < 3,000 ug/L based on TP guideline
3 % stream miles with 100 > TP > 50 ug/L EPA guideline

Appendix B: Table B3. Percent of stream miles in poor condition or affected by potential stressors for the Mid-Atlantic Highlands, four Highland ecoregions, three watersheds, and two states.

Constituents	MID-ATLANTIC REGION	ECOREGION				WATERSHED			STATE	
		North-Central Appalachians	Ridge & Blue Ridge	Valley	Western Appalachians	Chesapeake	Allegheny-Monongahela	Kanawha-Upper Ohio	Pennsylvania	West Virginia
Fish IBI[1]	31	43	14	31	30	23	31	41	27	44
EPT Index[1]	27	24	14	36	37	20	22	36	27	25
Nonnative Fish[2]	31	36	19	40	19	31	46	20	44	26
Fish Tissue Contamination[3]										
- Carcinogens	10	12	5	16	7	5	19	9	15	1
- Mercury	4	8	0	0	6	4	14	0	9	0
Mine Drainage[4]	14	24	0	0	24	3	20	21	16	13
Acidic Deposition[4]	11	24	8	2	0	11	26	7	14	14
Total Nitrogen[6]	4	2	1	15	24	7	2	17	8	1
Total Phosphorus[5]	5	1	1	3	20	2	2	13	9	5
Riparian Habitat	24	31	5	34	28	12	28	30	21	26
Instream Habitat	25	10	28	28	38	25	6	30	19	18
Watershed Condition[1]	25	27	10	35	31	21	36	22	38	9

1 % stream miles in poor condition
2 % stream miles with nonnative fish
3 % stream miles with at least one constituent above human health carcinogen criteria or above mammalian mercury criteria
4 % stream miles affected
5 % stream miles with TP>100 ug/L EPA guideline
6 % stream miles with TN > 3,000 ug/L, based on TP guideline

Appendix C: Glossary

Acid Deposition: A complex chemical and atmospheric phenomenon that occurs when emissions of sulfur and nitrogen compounds and other substances are transformed by chemical processes in the atmosphere, often far from the original sources, and then deposited on earth in either a wet or dry form. The wet forms, popularly called "acid rain," can fall as rain, snow, or fog. The dry forms are acidic gases or particulates.

Algae: Simple rootless plants that grow in bodies of water (e.g., estuaries) at rates in relative proportion to the amounts of nutrients (e.g., nitrogen and phosphorus) available in the water.

Anthropogenic: Originating from man, not naturally occurring.

Assessment: Interpretation and evaluation of scientific results for the purpose of answering policy-relevant questions about ecological resources, including (1) determination of the fraction of the population that meets a socially defined value and (2) association among indicators of ecological condition and stressors.

Atmospheric Deposition: The flux (flow) of chemicals and materials from the atmosphere to the earth's surface. Depending on the chemical or material, "dry" deposition (e.g., by particles) can be less than, equal to, or greater than "wet" deposition (e.g., precipitation).

Attribute: Any property, quality, or characteristic of sampling unit. For example, attributes of a tree, might include height and leaf type. For fish, such atributes would be size, feeding, or spawning habitat.

Base Flow: Sustained flow in a stream primarily from a groundwater discharge. Sometimes known as non-storm or dry weather flow.

Benthos: Plants or animals that live in or on the bottom of an aquatic environment such as a stream.

Biological Assemblage: A grouping of species from the same general category of living organisms such as fish, aquatic insects, hard wood trees, or riparian vegetation.

Biota: Living organisms including both plants and animals found in a given area.

Buffer: A solution resistant to pH changes, or whose chemical make up tends to neutralize acids or bases without a change in pH.

Carcinogenic: Cancer causing

Channelization: The artificial enlargement, straightening, or realignment of a stream channel.

Community: The assemblage of populations of plants and animals that interact with each other and their environment. The community is shaped by populations and their geographic range, the types of areas they inhabit, species diversity, species interactions, and the flow of energy and nutrients through the community.

Competitor: An organism rivaling another organism in the same area for food, habitat, or other resource in limited supply.

Conductivity: A measure of the capacity of water to conduct electricity. Conductivity provides an indication of the concentration of dissolved minerals in the water.

Detritus: Non-living organic matter (e.g., dead organisms or leaves) in water.

Ecology: The relationship of living things to one another and their environment, or the study of such relationships.

Ecoregion: A relatively homogeneous geographic area perceived by simultaneously analyzing a combination of causal and integrative factors including land surface form, soils, land uses, and potential natural vegetation.

Ecosystem: A natural unit formed by the interaction of a community of plants and animals with their environment (physical, chemical, and biological).

Effluent: The discharge to a body of water from a defined or point source, generally consisting of a mixture of waste and water from industrial or municipal facilities.

EMAP: Environmental Monitoring and Assessment Program - an EPA Office of Research and Development research program.

Eutrophication: A condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (e.g., phytoplankton). Algal decomposition may lower dissolved oxygen concentrations. Although eutrophication is a natural process in the aging of lakes and some estuaries, it can be accelerated by both point and nonpoint sources of nutrients.

Food Web: An assemblage of organisms in an ecosystem, including plants, herbivores, and carnivores, which shows the relationship of who eats whom.

Habitat: The place where a population or community (e.g., microorganisms, plants, animals) lives and its surroundings, both living and non-living.

Headwater: The area that is the source or origin of a stream, above which no stream exists.

Index: A summary of indicator scores.

Invertebrates: Animals that lack a spinal column or backbone, including molluscs (e.g., clams and oysters), crustaceans (e.g., crabs and shrimp), insects, starfish, jellyfish, sponges, and many types of worms that live in the benthos.

Land Cover: Anything that exists on, and is visible from above, the earth's surface. Examples include vegetation, exposed or barren land, water, snow, and ice.

Land Use: The way land is developed and used in terms of the kinds of anthropogenic activities that occur (e.g., agriculture, residential areas, industrial areas).

Landscape: The set of traits, patterns, and structure of a specific geographic area, including its biological composition, its physical environment, and its anthropogenic patterns. An area where interacting ecosystems are grouped and repeated in similar form.

Mammalian: Related to animals that are warm-blooded higher vertebrates that nourish their young with milk and have skin with hair

Map Scale: A statement of a measure on the map and the equivalent measure on the earth, often expressed as a representative fraction of distance, such as 1:24,000.

Metric: A measurement or mathematical function used to represent some property or feature of living organisms. For example, the number of fish species intolerant of pollution is one metric included in the fish Index of Biotic Integrity.

Mine Tailings: Residue left from mining coal, ores, or other material. These residues can leach or contribute pollutants to streams.

Monitoring: The periodic or continuous collection of data that is used to determine the condition ecological resources.

Nonpoint Source: Refers to pollution that enters water from dispersed and uncontrolled sources, such as surface runoff, rather than through pipes.

Nutrients: Essential chemicals (e.g., nitrogen and phosphorus) needed by plants for growth. Excessive amounts of nutrients can lead to degradation of water quality (i.e. eutrophication) by promoting excessive growth, accumulation, and subsequent decay of plants, especially algae (phytoplankton).

Order: A taxonomic unit in the scientific classification for plants and animals. an order is the unit in between family and class.

Organic Contaminants: Carbon containing waste originating from domestic or industrial sources contained in plant or animal matter

Parasite: An organism that lives off another organism or host for survival and usually injures the host.

Perturbation: A disturbance of motion, course, arrangement or structure that creates confusion.

Point Source: Refers to a source of pollutants from a single point of conveyance, such as a pipe. For example, the discharge from a sewage treatment plant or factory is a point source.

Population: A group of organisms that a capable of interbreeding, which typically represents a biological level of organization equivalent to a species.

Predator: An animal that kills and consumes other animals for its food.

ppb: Parts per billion equivalent to micrograms per kilogram (µg/kg) or micrograms per liter (µg/L).

ppm: Parts per million; equivalent to micrograms per gram (µg/g) or milligrams per liter (mg/L).

Sampling Methods: Procedures and practices used to collect or measure physical, chemical or biological material (e.g., temperature, water, organisms) in or from the environment.

Scale: A distinctive relative size, extent or degree of an area. For example, one scale of measure or study might be an individual stream while a larger scale of measure or study might be a watershed that contains many streams.

Sediment: Mud, sand, silt, clay, shell debris, and other particles that settle on the bottom of rivers, lakes, estuaries, and oceans.

Species: A group of individuals similar in certain morphological and physiological characteristics that are capable of interbreeding and are reproductively isolated from all other such groups.

Stream Reach: Portion of a stream; typically of a stream between the point where a stream enters (confluence) above to the point where a stream enters (confluence) below. Stream reaches can be a specific distance along a stream that was sampled for fish or aquatic insects.

Stressor: Any physical, chemical, or biological entity that can cause or induce an adverse response.

Surface Water: Water in streams, lakes or estuaries that is visible on the surface of the earth. In contrast to groundwater, which is below the ground and not visible.

Threatened, or Endangered: Living organisms placed in a special category for protection by the Endangered Species Act of 1973.

Toxic Substances (or material): Chemical compounds that are poisonous, carcinogenic, or otherwise directly harmful to plants and animals.

Value: A characteristic of the environment that contributes to the quality of life of an area's inhabitants; for example, the ability of an area to provide desired functions such as food, clean water and air, aesthetic experience, recreation, and desired animal and plant species.

Water Column: An imaginary cylinder of water from the water surface to the sediment that is used to describe the location of physical, chemical or biological properties or entities.

Watershed: The entire area of land whose runoff of water, sediments, and dissolved materials (e.g., nutrients, contaminants) drain into a river, lake, estuary, or ocean.

Wetlands: Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or where shallow water covers the land and where at least one of the following attributes holds: (1) at least periodically, the land supports aquatic plants predominantly; (2) undrained hydric soils are the predominant substrate; and (3) at some time during the growing season, the substrate is saturated with water or covered by shallow water (Cowardin et al. 1979). An area that is saturated by surface or ground water with vegetation adapted for life under those soil conditions. Examples of wetlands include swamps, bogs, fens, and marshes.

Zooplankton: Very small, some even microscopic, animals that are suspended in the water and have very limited powers of moving against currents. These animals move primarily because the water carries or transports them.