United States
Environmental Protection
Agency

Office of Research and
Development
Washington, DC 20460

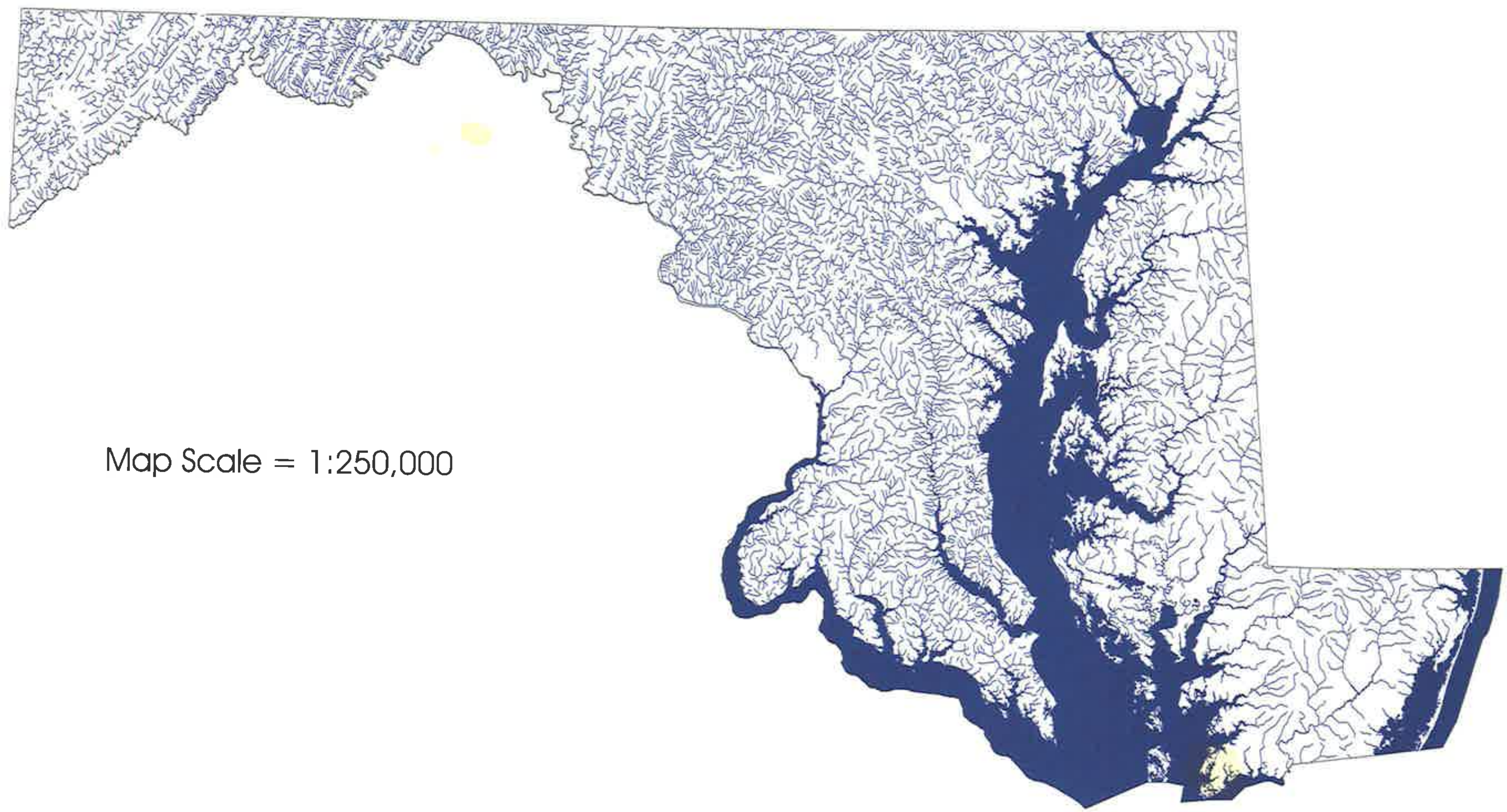
EPA/903/R-99/023
December 1999
www.epa.gov

EPA

From the Mountains to the Sea

The State of Maryland's Freshwater Streams

State of Maryland Department of Natural Resources



Map Scale = 1:250,000

Maryland has an intricate network of more than 8,800 miles of freshwater streams. If stretched end-to-end, they would reach from Baltimore across the Atlantic Ocean to South Africa.

From the Mountains to the Sea:

The State of Maryland's Freshwater Streams

Authors

Daniel Boward, Paul Kazyak, Scott Stranko
Martin Hurd, Anthony Prochaska

Maryland Department of Natural Resources

Tawes State Office Building, C-2
580 Taylor Avenue
Annapolis, MD 21401

with support from

United States Environmental Protection Agency
National Health and Environmental Effects Research Laboratory
Atlantic Ecology Division

27 Tarzwell Drive
Narragansett, RI 02882

and

Region III
Environmental Services Division

1650 Arch Street
Philadelphia, PA 19103

NOTICE

The information in this report was funded in part by the United States Environmental Protection Agency (Environmental Monitoring and Assessment Program, Office of Research and Development) through the Atlantic Ecology Division. Support was provided to the Maryland Department of Natural Resources by EPA Cooperative Agreement #CR-825488-01-0, T. Pheiffer, Project Officer. The report was subjected to the EPA's peer and administrative review, and has received approval for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

The suggested citation for this report is: D.M. Boward, P.F. Kazyak, S.A. Stranko, M.K. Hurd, and T.P. Prochaska. 1999. *From the Mountains to the Sea: The State of Maryland's Freshwater Streams*. EPA 903-R-99-023. Maryland Department of Natural Resources, Monitoring and Non-tidal Assessment Division, Annapolis, Maryland.

ABSTRACT

The Maryland Biological Stream Survey, conducted by the Maryland Department of Natural Resources, sampled about 1,000 randomly-selected sites on first through third order freshwater streams throughout Maryland from 1995 to 1997. Biota (fish, benthic macroinvertebrates, herpetofauna) and water chemistry were sampled and physical habitat quality was assessed at each site. Land use/land cover in the watershed upstream of each site was also determined. This report is intended to present the results of the Survey to a broad array of audiences, including the general public, about the condition of wadeable freshwater streams in Maryland. The report is also intended to serve as a tool for resource managers and planners for developing policy and targeting areas for restoration and preservation. For example, the report describes the impact of urbanization on fish and benthic macroinvertebrate communities (using indices of biotic integrity), herpetofauna, and stream temperatures. These findings should be useful for land use planning in areas of the state slated for development. The report also describes the extent of physical habitat degradation, including riparian buffer conditions. Other topics include acidification; nutrient enrichment; biodiversity; introduced fish; and rare, threatened, and endangered fish species. The reader is provided with a historical context in which to view the current health of Maryland's streams. Suggestions are included on how individuals can work with organizations to protect and restore their local streams.

Key Words: Streams; Maryland; Chesapeake Bay; Environmental Monitoring; Ecological Assessment; River Basin; Watershed; Aquatic Life; Biological Diversity; Biological Indicators; Water Quality; Physical Habitat

Greetings from the Maryland Department of Natural Resources and the U.S. Environmental Protection Agency

Deer Creek in the Susquehanna River basin.
Photo courtesy of MD DNR

Dear Reader:

Maryland's streams represent a vital, life-giving resource to its citizens. In addition to providing clean water to support life in Chesapeake Bay, the world's most productive estuary, our streams provide habitat for a multitude of plants and animals. From cascading mountain brooks to meandering coastal streams, flowing waters are sought out for their great beauty, recreational value, and source of tranquility in a fast-paced world. For these reasons and more, protection and restoration of our aquatic world need to be high on our list of priorities.

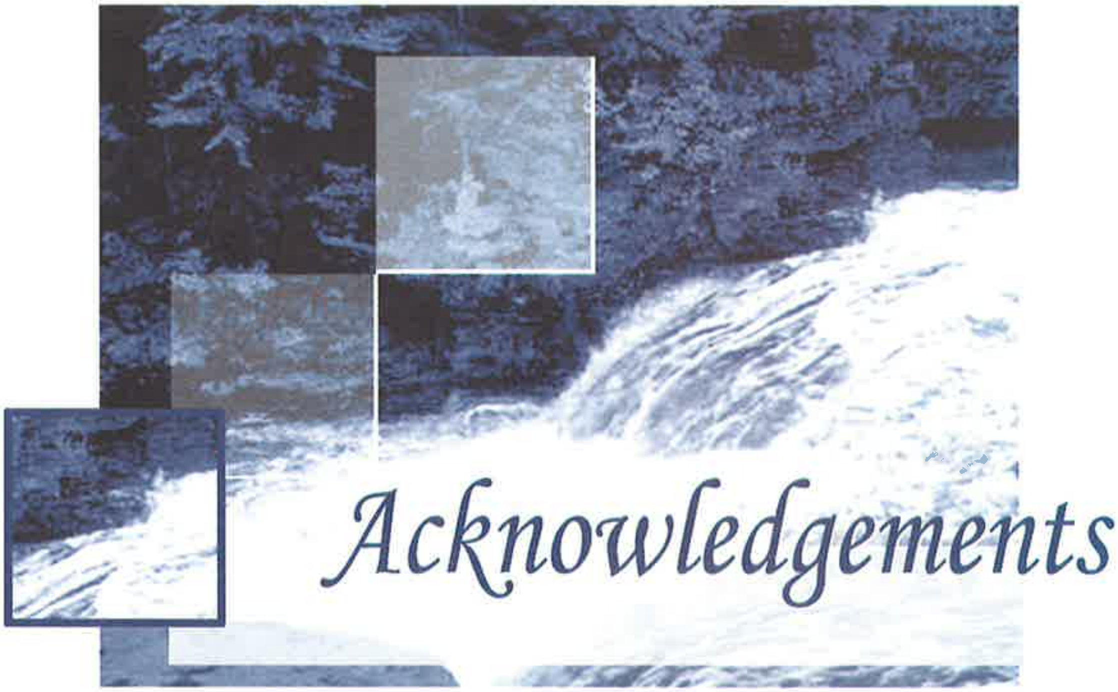
Because the health of our streams reflects conditions on the lands that they drain, the health of our aquatic life is very much dependent on the health of our watersheds. What is the current condition of our streams? Which human activities have the most effect on our streams and where are these activities most pronounced? This report begins to answer these types of questions using information from the Maryland Biological Stream Survey, or MBSS, developed by the Maryland Department of Natural Resources and supported by the U.S. Environmental Protection Agency.

Maryland is working on stream protection in a variety of ways. Governor Parris N. Glendening's nationally acclaimed Smart Growth and Neighborhood Conservation initiative recognizes the link between how we develop our land and the quality of our waterways. By financially supporting new growth only in existing communities or areas locally designated for growth, and by permanently preserving forested buffers and other valuable land through the new Rural Legacy Program, the Smart Growth initiative bolsters efforts to keep Maryland streams clear and clean.

In the past, water monitoring programs have focused largely on the chemical make-up of our streams. With the MBSS, Marylanders can be proud that the state is leading the way in providing a state-of-the-art assessment and management tool for our streams. By embracing the new science of ecological assessment and combining information on water chemistry, physical habitat, and aquatic life, we have gained a more realistic picture of the health of our streams, and we are proud to share some of our findings with you. By providing you with this first of a new generation of reports on Maryland's streams, we hope to spur your interest in streams and lead you to an increased awareness and involvement in the protection and restoration of these irreplaceable natural resources.

Parris N. Glendening
Governor
State of Maryland

Michael McCabe
Acting Deputy Administrator
U.S. Environmental Protection Agency



Acknowledgements

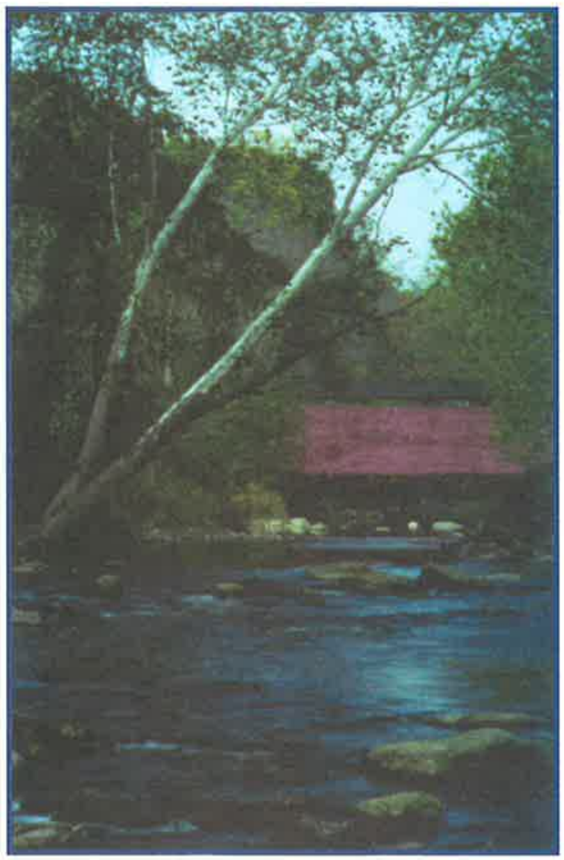
From the Mountains to the Sea... The State of Maryland's Freshwater Streams

This report was produced by the Maryland Department of Natural Resources (MD DNR), Resource Assessment Service, Monitoring and Non-tidal Assessment Division, through Cooperative Agreement Number ***CR-825488-01-0*** from U.S. EPA Office of Research and Development.

Authors: Daniel Boward, Paul Kazyak, Scott Stranko, Martin Hurd, and Anthony Prochaska

Contributors: We wish to thank several people for their valuable contributions to this report. First, the following people contributed greatly to this report by managing and analyzing data and working to develop the indicators used here: Mark Southerland, Nancy Roth, and Janis Chaillou of Versar, Inc.; Sam Stribling, Jeffrey White, and Ben Jessup of Tetra Tech, Inc.; and Ray Morgan and Lenwood Hall of the University of Maryland.

We also wish to thank Ron Klauda, Paul Massicot, Ceil Petro, William Jenkins, Robert Lundsford, Ray Dintamin, Frank Dawson, John McCoy, Larry Lubbers, and Ken Yetman



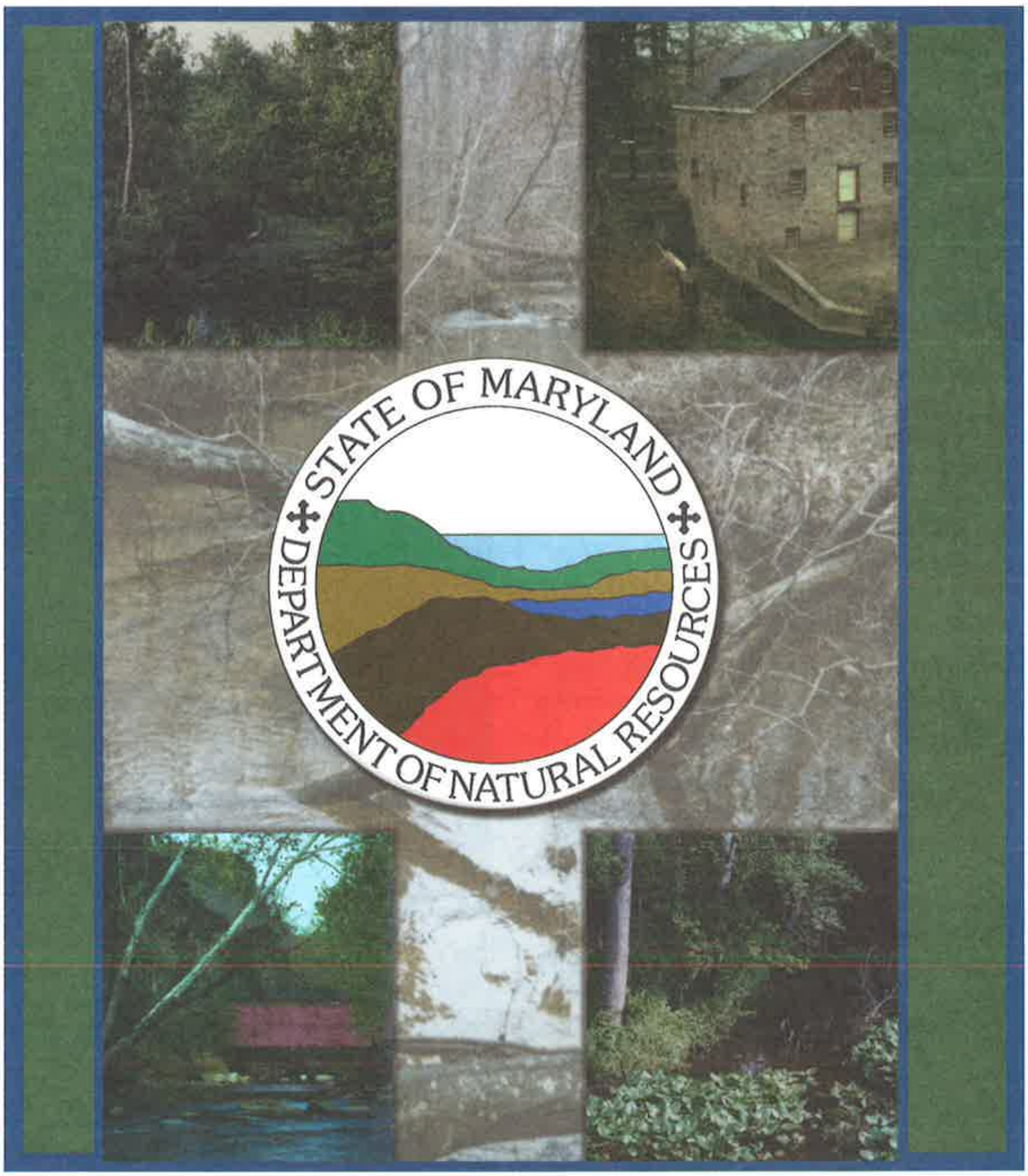
Big Elk Creek in the Elk River basin
Photo courtesy of MD DNR

of DNR; Tom Pheiffer, Pat Bradley, Tom DeMoss, Steve Paulsen, Chuck Kanetsky, Maggie Passmore, and John Stoddard of U.S. Environmental Protection Agency; Ron

Preston of the Canaan Valley Institute; Karl Blankenship of the Alliance for the Chesapeake Bay; Paul Angermeier of the U.S. Geological Survey, and Tom Simpson of the Maryland Department of Agriculture for reviewing the report. Last, but certainly not least, we thank Ray Morgan, Lenwood Hall, Matt Klein, and Bill Killen of the University of Maryland for data collection and Derek Wiley, John Stavlas, Natasha Davis, Ann Lenert, Dung Nguyen, and Lamar Platt of DNR for data analysis and presentation.

This report has been reviewed and approved for publication by the U.S. Environmental Protection Agency. Approval does not signify that the contents necessarily reflect the views and/or policies of the EPA. Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA approval, endorsement, or recommendation.

On the cover: Hunting Creek tumbles over Cunningham Falls in Western Maryland



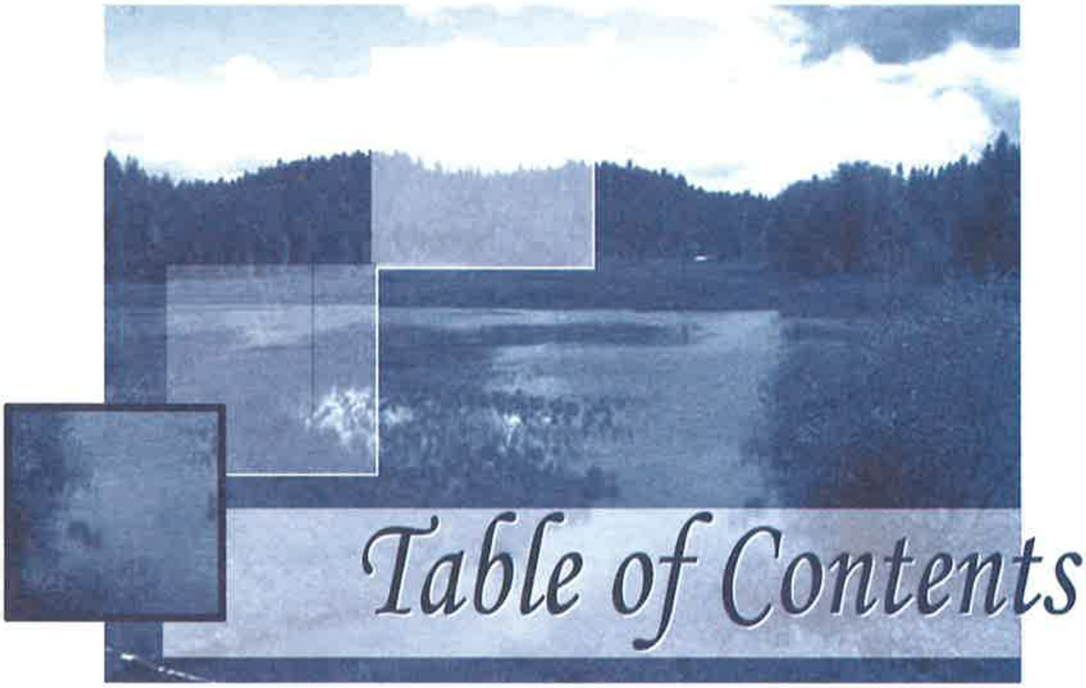


Table of Contents

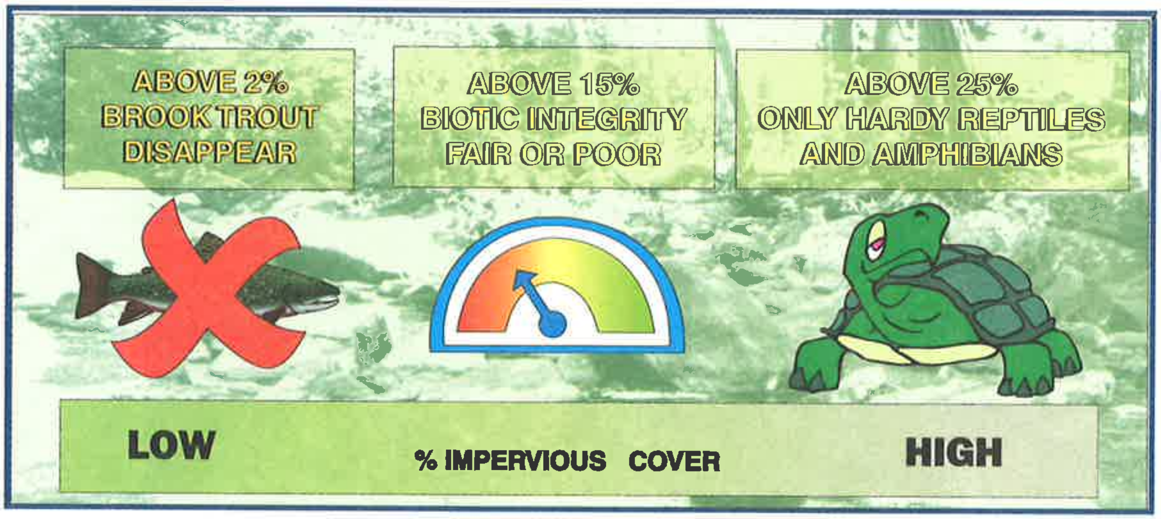
The purpose of this report is to begin to address the current health of Maryland's freshwater streams and to determine the impacts of human activities on these waters. The data base compiled for this report will also be used in the preparation of Maryland's next biennial water quality report to Congress. With the availability of this new statewide information, a logical next step will be to evaluate it's applicability to regulatory activities. A multi-agency effort is now underway in Maryland to determine how these data on the State's streams can be used to develop biocriteria for water quality regulatory programs (see "The Future of Maryland's Streams" section).

Below are the major findings from three years of stream sampling (1995-1997) by the Maryland Biological Stream Survey (MBSS...or the Survey). Data from about 1,000 randomly-selected sites were used to assess Maryland's non-tidal freshwater streams from the Appalachian Mountains of Garrett County to the Lower Eastern Shore. Aquatic animals (fish, benthic macroinvertebrates, reptiles, and amphibians), physical habitat, and water chemistry were assessed at each site, as well as land use in the upstream watershed. Indices of Biotic Integrity for fish and benthic macroinvertebrates were used to tell us the overall ecological health of the sampled streams. For the first time, we now have a comprehensive and scientifically-defensible tool for telling us how many stream miles, either within certain river basins or statewide, are healthy or not. This tool also gives us insight into some of the causes of stream degradation. For a detailed description of the design and methods used by the Survey, see the Technical Appendix at the end of this report.

Land Use Impacts

Current patterns of urbanization have caused significant impacts to Maryland's streams. If urban sprawl continues to consume our forests and farmlands in the same manner as in the past, more Maryland streams will likely degrade in the years to come. For example, the health of many streams is largely influenced by the amount of impervious land cover upstream. Three indicators of stream health help us illustrate the harmful effects of urbanization on stream biota. When watershed imperviousness exceeds 25%, only hardy, pollution-tolerant reptiles and amphibians can thrive, while more pollution-sensitive species are eliminated. Above 15% watershed imperviousness, stream health is never rated good, based on a combined fish and benthic macroinvertebrate Index of Biotic Integrity. Even low levels of imperviousness affect streams. When upstream impervious land cover is above 2%, pollution-sensitive brook trout are never found. Streams most affected by urbanization are in the Baltimore-Washington Metropolitan portions of the Patapsco and Potomac Washington Metro river basins.

Urbanization continues to threaten Maryland streams. If the current rate of urban sprawl continues, more Maryland streams will likely degrade.



More than half of Maryland's stream miles have unnaturally elevated nutrient levels. These levels are generally highest in watersheds with more agricultural land use.

The primary and most widespread source of nutrients in streams is runoff from farm fields, although excess nutrients enter streams from several other sources, such as acid rain, lawns, golf courses, and septic systems. About 57% of the state's stream miles have unnaturally elevated nutrient concentrations, and these concentrations are generally higher in watersheds with more agricultural land use. Some sites with greater than 50% agricultural land use upstream contain nitrate concentrations as high as 24 mg/L. Two heavily farmed river basins—the Chester and Middle Potomac—have several streams with very high nitrate concentrations. Although excess nitrate in small streams may produce an overabundance of algae and aquatic plants, the greatest impacts are realized downstream in tidal rivers and Chesapeake Bay.

Habitat Loss

Physical habitat degradation is the most widespread source of stress on Maryland's streams, and is extensive in all but one river basin.

The loss of high-quality physical habitat is widespread in Maryland streams due to many factors, such as elimination of forested riparian (streamside) buffers and channelization. Only 20% of all stream miles in Maryland have good physical habitat quality, while 52% are in poor condition. More than one-quarter (27%) of Maryland's stream miles have no vegetated riparian buffers and thus are poorly protected against stormwater runoff. Because forested buffers are a key component of healthy streams and a healthy Chesapeake Bay, we need to replant those streamside forests that have been lost and redouble our efforts to protect those that remain.

About 17% of all stream miles statewide are channelized. Channelized streams are unhealthy for several reasons, including poor habitat and elevated water temperatures. They also serve to transport sediment, nutrients, and pollutants to the Chesapeake Bay more rapidly than streams with natural meandering channels and healthy biota.

This urban stream channel has been drastically altered to increase stormwater drainage. *Photo by Paul Kazyak*

Because of the more than 1,000 migration barriers across Maryland streams and rivers, much of the stream habitat once available to migratory fish is now unaccessible. For example, American eel populations have been diminished by these migration barriers.

Acidity

Acid rain is the most important and most widespread source of acidity in Maryland streams, affecting nearly one-fifth of the state's stream miles. Natural acidification and acid mine drainage each acidify about 3% of all stream miles, while runoff of fertilizers acidifies about 4%. Low stream pH has a dramatic effect on fish. While streams with pH greater than 6 have more than 9,000 fish per stream mile, those with pH less than 5 contain no fish.

Biological Health

Based on a combined fish and benthic macroinvertebrate Index of Biotic Integrity, about 12% of all stream miles in Maryland are in good condition, 42% are fair, and almost one-half (46%) are poor. Poor streams are considered unhealthy compared to reference (healthiest) streams. Good and fair streams are considered healthy compared to reference streams. Good streams are comparable to the highest quality reference streams and fair streams are comparable to the remainder of the reference streams. These two communities of stream animals give us valuable insights into cumulative impacts (such as acid rain, urban and agricultural runoff, and point source discharges) on our streams.

Biological Diversity

In spite of the many stressors on Maryland's streams, they still harbor an incredible diversity of animal life. For example, 45 species of amphibians and reptiles occupy Maryland streams, with 91% of all stream miles having at least one species. About 350 types of benthic macroinvertebrates live among the rocks, roots, wood, sand, and mud of Maryland's streams where they process nutrients and provide food for fish, birds, and mammals.

The southern leopard frog is among the 45 species of reptiles and amphibians found in and along Maryland streams during the Survey.
Photo by Brian Stranko

About 100 fish species swim in Maryland streams—the most abundant is the pollution tolerant blacknose dace. Six fish species are listed as rare, threatened or endangered and an additional 14 species were found during the Survey at only a few locations. These species may be at risk and are thus candidates for future listing.

Summary of Stressors

Results of the Survey can help answer important management questions about the relative impacts and geographic extent of different stressors on Maryland streams (Table 1). The most extensive and widespread source of stress is physical habitat degradation, which is extensive in all but one of Maryland's river basins (Elk River). Inadequate riparian buffers, unstable stream banks, and channelization all contribute to physical habitat degradation.

Major water quality stressors include excess nutrients, acid rain, and acid mine drainage. Acid rain is an extensive problem, primarily in Western Maryland and on the Lower Western Shore, while acid mine drainage problems are confined to Western Maryland.

There are many stressors that degrade Maryland's streams. Together, we can all help protect those that are still healthy.
Photo courtesy of MD DNR

Based on the health of fish and benthic macroinvertebrate communities, only about one in ten miles of streams are in good condition, while about half are poor.

Table 1. Summary of key stressors to Maryland's freshwater streams by major river basin. Colors represent the best estimate of the severity and extent of each stressor. Red and yellow indicate severe and moderate stress, respectively. No color indicates relatively little impact from a stressor within a basin.

	Nutrient Enrichment	Acid Rain	Acid Mine Drainage	Inadequate Riparian Buffer	Unstable Banks	Channelization	Poor Overall Physical Habitat
Youghiogheny	Yellow	Red	Red	Yellow	Yellow		Red
North Branch Potomac	Yellow	Red	Red	Yellow	Yellow		Red
Upper Potomac	Yellow	Red		Yellow	Red	Yellow	Red
Middle Potomac	Red			Red	Red		Red
Potomac Wash/Metro	Red			Red	Yellow	Yellow	Red
Patuxent	Yellow	Yellow		Yellow	Red		Red
Patapsco	Red			Red	Red	Yellow	Red
Gunpowder	Red			Red	Red		Red
Lower Potomac	Yellow	Red		Yellow	Red		Red
West Chesapeake	Yellow	Yellow		Yellow	Red		Red
Bush	Red			Red	Red		Red
Susquehanna	Red			Red	Red		Red
Elk	Red			Red	Red	Yellow	Yellow
Chester	Red			Red	Red	Yellow	Red
Choptank	Red			Red	Red	Yellow	Red
Nanticoke/ Wicomico	Red			Red	Red	Red	Red
Pocomoke	Red			Red	Red	Red	Red

Introduction

With the Appalachian Mountains to the west and the beaches of the Atlantic Ocean to the east, Maryland is a state of geographic diversity. Often called "America in Miniature," it is 12,189 square miles of rugged mountains, fertile valleys, rolling hills, and coastal flatlands. It is also a mosaic of landscapes. Forests, farm fields, suburbs, and dense urban areas are found throughout the state. And in the center of it all is Chesapeake Bay...one of Maryland's most precious natural resources and a true national treasure.

Maryland's freshwater streams mirror this diversity. From the cascading rapids of Muddy Creek Falls in Garrett County, to the sluggish ***blackwater**** of Zekiah Swamp in Charles County, our more than 8,800 miles of freshwater streams are a valuable resource for us all. They are the lifeblood of the land around us. They connect our backyards, shopping malls, and farm fields with the Bay and the ocean. Our streams provide us with drinking water, places to swim, fish, canoe, or places to simply stop and contemplate, away from the bustle of daily life. In large measure, they also determine the health of Chesapeake Bay.

In addition to their values to humans, many of our streams are biological wonderlands—with myriad species of aquatic plants and animals that often go unseen to all but the most astute observer. In swiftly-moving water, sluggish snails scrape tiny colonies of microscopic ***protists*** from rocks. In deep, dark pools, shrimp-like ***amphipods*** nibble last fall's maple leaves, producing ***detritus*** for downstream food webs. In a nearby mass of submerged tree roots, a crafty predatory dragonfly larva pounces on and consumes an unsuspecting mayfly...only to be consumed itself by a

Most Marylanders live within a 15 minute walk of a stream.

Maryland's Diverse Streams.
On its way to the Youghiogheny River in Garrett County, Muddy Creek Falls tumbles through Swallow Falls State Park (right). Worcester County's Nassawango Creek (left) meanders to the Pocomoke River.
Photo by Brian Stranko (left) and courtesy of MD DNR (right)

*terms in the glossary are ***highlighted*** at first usage

Ninety-five percent of Maryland's streams flow into Chesapeake Bay. Some streams flow either toward the Gulf of Mexico or through the Coastal Bays to the Atlantic Ocean.

voracious brook trout. The trout, of course, may end up as a delicious human dinner. Scenes like these occur every day in many of our streams and we humans play an increasingly large part in directing them; for it is how we live our lives that determines the health of the streams around us.

Before we begin our evaluation of the health of Maryland's streams, we must first understand the natural diversity of lands within the state and how we humans have altered the land to suit our purposes. Because streams may be quite different depending on their location, we will examine how geology and terrain vary across the state and the many impacts resulting from human activities.

Geographic Setting

Maryland is divided into three broad geographic areas (Figure 1): the Appalachian Plateau, Piedmont, and Coastal Plain provinces. Each has its own combination of soils, geology, vegetation, and terrain that function together to produce different stream types. To the east, the flat, low-lying Eastern Shore and the rolling uplands of the Western Shore make up the Coastal Plain. This area envelops the Chesapeake Bay and has soils of sand, silt, or clay and slow-flowing streams with soft sand or gravel bottoms. The Coastal Plain is separated from the remainder of the state by the ***Fall Line***, directly west of which are the undulating hills of the Piedmont. Most Piedmont streams are of moderate slope, with rock or bedrock bottoms. West of the Piedmont, the geographically diverse Appalachian Plateau (composed of the Blue Ridge, Valley and Ridge, and Allegheny Plateau) has expansive limestone-rich valleys, broadly sloping mountains, and high, steep ridges. Streams in the Appalachian Plateau are mostly rocky and may ***meander*** through wide floodplains or

What is the Fall Line?

A line roughly along Interstate 95 joining areas of relatively steep gradient on several rivers on Maryland's western shore. The line marks the geographical area where each river descends from the hilly Piedmont to the flat and sandy Coastal Plain. It also marks the limit of upstream commercial navigation, which, from an historical perspective, explains why most Marylanders live and work along this corridor.

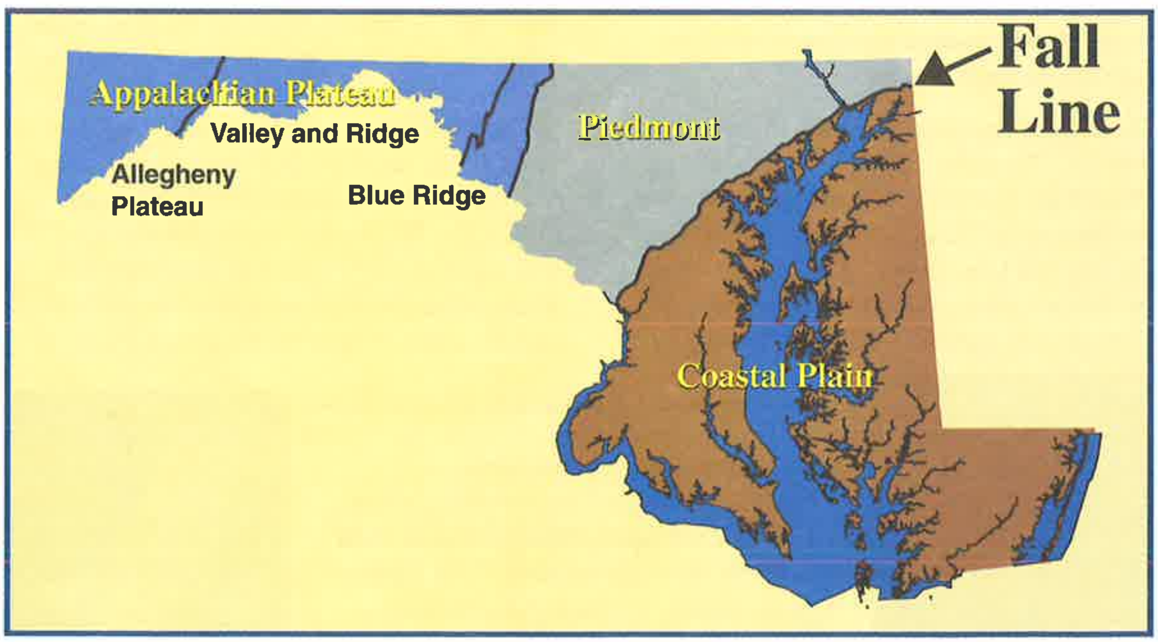


Figure 1. Maryland has 3 broad geographic areas: the Coastal Plain, Piedmont, and Appalachian Plateau. The Appalachian Plateau has the most diverse landscape.

cascade down steep mountainsides. Yet even in these mountainous areas, some streams course through wetland glades and take on much the same character as their Eastern Shore counterparts.

On a finer scale, Maryland is divided into 18 large ***river basins***—the geographic areas of interest for this report—each containing an intricate network of streams (Figure 2). The Middle Potomac basin is the largest of these basins, with 925 square miles and 1,102 stream miles. The Bush basin is the smallest, with just 195 square miles and 186 stream miles. Some basins like the Patuxent and Patapsco lie completely within Maryland, but most extend beyond Maryland into Pennsylvania, Delaware, or West Virginia. By examining stream health within river basins, we provide a tool for assessing the effectiveness of watershed management programs such as Maryland's Tributary Strategies. We also can target certain areas of the state for stream protection and restoration programs and develop a standard geographic unit for assessing trends in stream health over the years to come.

Maryland is also a mosaic of land uses. Today, only 42% of the state is forested (Figure 3) while prior to European settlement, more than 90% of the state was forested. The most heavily forested river basins are the North Branch Potomac and Youghiogheny in Western Maryland. Most of the state's remaining wetlands (about 8% of the total area) are concentrated on the Lower Eastern Shore. A little more than one third (34%) of Maryland's land is used for farming. The Chester and Middle Potomac river basins are both more than one-half farmland. Urban and suburban land (residential, commercial, industrial, institutional, and extractive) make up about 16% of Maryland and are concentrated in the Washington-Baltimore metropolitan area, primarily along the Fall Line and eastern portion of the Piedmont in the Potomac Washington Metro and Patapsco basins. Between now and the year 2020, the state's population is expected to increase from 5,244,000 to 6,000,000 or about 15%. Thus, the urban and suburban proportion of land will likely increase to accommodate these new Maryland residents.

About 16% of Maryland's land area is urban. This percentage is expected to grow to about 21% in the next 25 years.

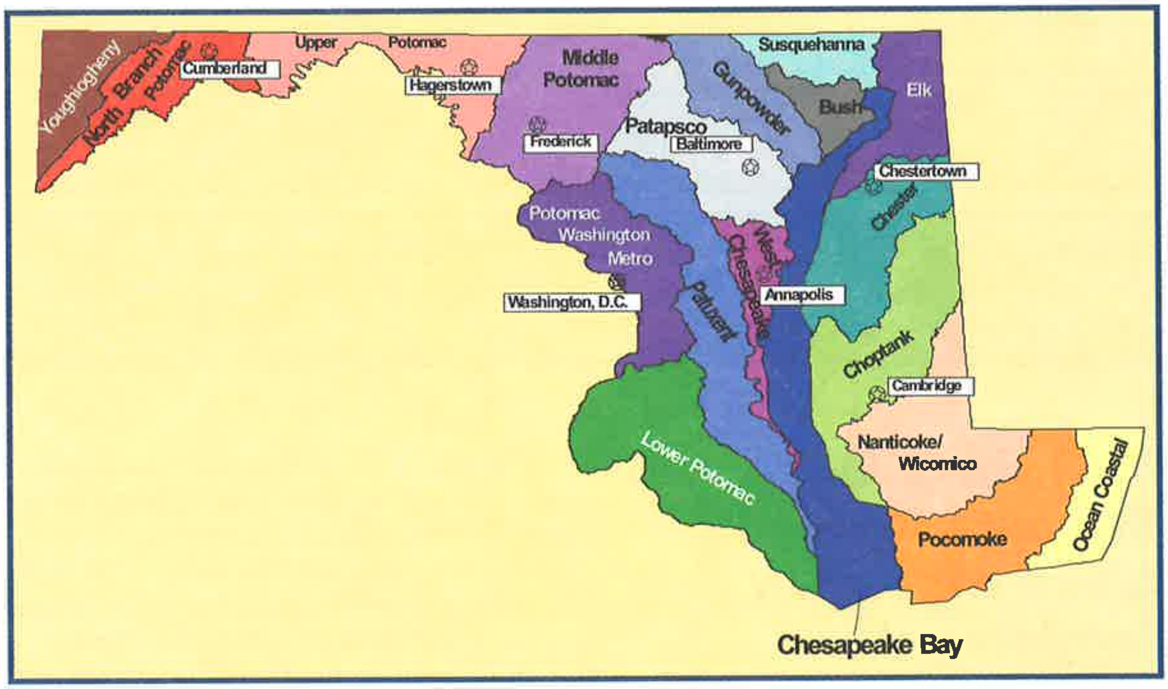


Figure 2. Maryland has 18 large river basins. All but two, the Youghiogheny and Ocean Coastal, flow to the Chesapeake Bay. Because it contains few non-tidal, freshwater streams, Survey information from the Ocean Coastal basin is not included in this report.

Only about 80 acres of Maryland's forests have never been logged.

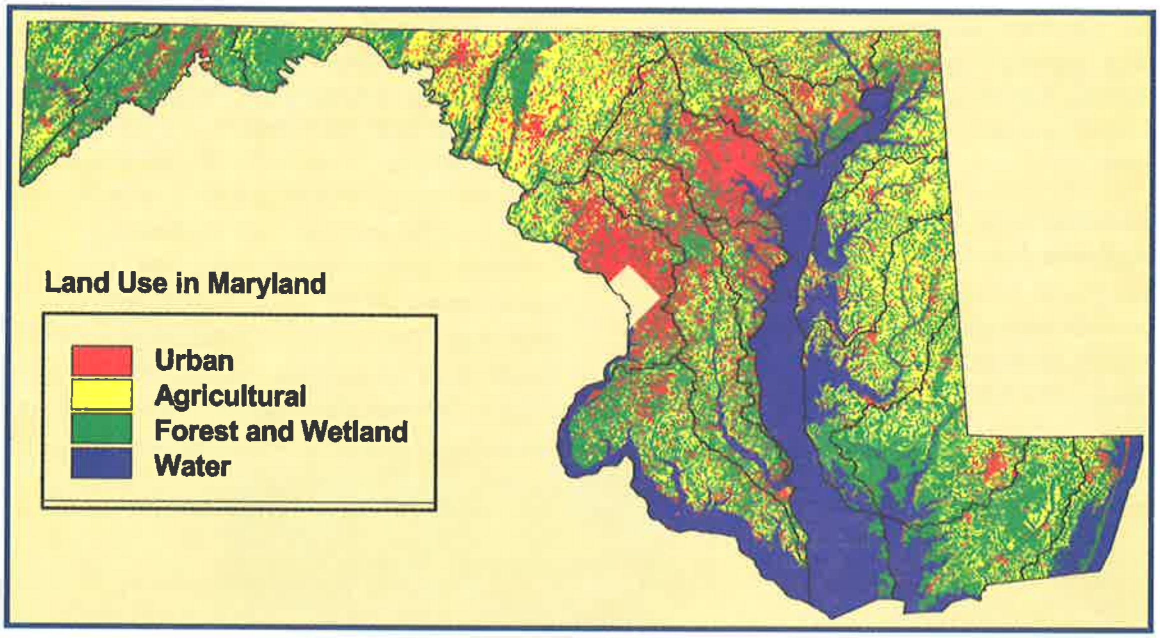


Figure 3. Maryland is a mosaic of land uses. While most urban land is concentrated in the Washington-Baltimore metropolitan area, much of the Eastern Shore and central part of the state is agricultural.

Human activity has profoundly affected rivers and streams in all parts of the world, to such an extent that it is now extremely difficult to find any stream which has not been in some way altered, and probably quite impossible to find any such river.

— H.B.N. Hynes

How Have Our Streams Changed Since European Settlement?

To better understand the current state of Maryland streams, we should look at how they have changed in the past three centuries. When European settlers first arrived in Maryland in the early 1600s, our streams meandered through mostly unbroken forests and wetlands. Beavers were abundant—their ponds provided diverse aquatic habitats. Old trees died and fell into streams, creating a labyrinth of logs, limbs, and roots that sheltered fish and other aquatic animals. Rain soaked into the sponge-like forest floor, slowly replenishing streams with fresh groundwater during dry periods.

As the early settlers dispersed throughout Maryland after Lord Calvert's first visit in 1634, trees were cut to provide fuel and to make way for farm fields and settlements. Beavers were eliminated while trying to meet an insatiable demand for fur. To convert wetlands to farms, streams were straightened and cleared of wood for better drainage. Over time, forests along streams were largely eliminated to maximize the ability of the land to produce crops for the settlers and their farm animals, and also for export back to Europe. With the trees gone and replaced by tilled and grazed agricultural lands, soil was washed from the land and the streams became warmer, muddier, and more vulnerable to erosion. Nutrients, once retained by the unhurried flow through wetlands and percolated through the spongy forest floor, were quickly routed to Chesapeake Bay. Eventually, agriculture became a dominant feature of Maryland landscape and remains important today. Thus, these settlers had a much greater impact on Maryland streams than did the Native Americans who first occupied the land.

As towns became cities during and following the Industrial Revolution, many streams became open sewers or were straightened and routed through barren concrete channels to quickly remove storm water from the nearby developed land and minimize flooding. No longer could rain soak slowly into the ground. During storms, it quickly ran off parking lots, roads, rooftops, and other ***impervious surfaces*** carrying with it a load of pollutants. Indeed, streams were viewed primarily as a means to convey wastes and stormwater to some "out of sight" downstream place.

Wilson Mill on Deer Creek.
Photo by Paul Kazyak

The Industrial Revolution also brought an increase in pollution from the air and from underground that continues to acidify our streams. From as far away as the Ohio River Valley and other Midwestern U.S. industrial areas (and as near as our own car exhaust pipes), acidifying chemicals are sent into the atmosphere, only to fall back to the earth as ***acid rain***. In some areas, acid rain has eliminated all but the hardiest aquatic life in poorly ***buffered*** streams. Our appetite for energy to fuel our factories and heat our homes resulted in more coal mines, especially in Western Maryland. Today, drainage from abandoned mines continues to pollute many streams with toxic acid-laden water.

In summary, there are no pristine freshwater streams in Maryland. All have been affected by humans in some way.

This Report

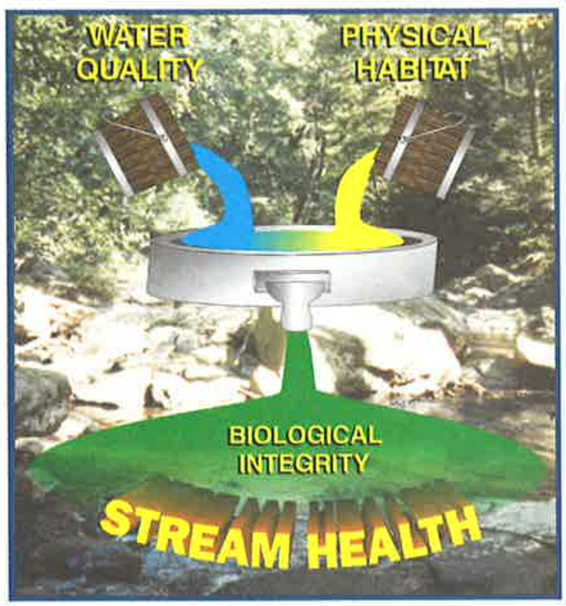
Many Marylanders want to help protect and restore our freshwater streams. To do this, we need to work together. Individual citizens, watershed organizations, businesses, and local, state, and federal agencies all have a role to play. But to help our streams, we must have a benchmark for how healthy they are now. We must learn what aspects of our streams are healthy or unhealthy and work to understand what is causing the problems, so we can improve stream health across the state.

The purpose of this report is to describe the health of, and impacts to, Maryland's freshwater non-tidal streams using information from the Maryland Biological Stream Survey, or the Survey, conducted by Maryland Department of Natural Resources from 1995 to 1997. Although the report paints a picture of overall stream health throughout the state and by river basin, many readers may wish to use it as a guide for information on streams in their own back yard or to learn how they can help improve the quality of our streams for themselves, for their children, and for their children's children. With a better understanding of Maryland streams, we all can learn from our past mistakes and become more effective stewards of these wonderful ecosystems.

Impervious surfaces include parking lots, rooftops, roads, and sidewalks. They prevent rain and melting snow from soaking into the ground, thus increasing stream flows during storms and reducing stream flows during dry periods.

The State of Maryland's Freshwater Streams

When asked the question, "How healthy is this stream?" many of us first think of drinking its water. If the water is safe to drink, we may say, then the stream is healthy. For many years, stream protection and restoration efforts focused only on water chemistry, without much consideration of other ecosystem components. But there's much more to the story. Although water quality certainly is an important part of overall stream health, we must also consider the quality of the physical ***habitat***—the structure that forms the home for the stream's inhabitants—and the inhabitants themselves. What is the stream's ***biological integrity***? Are biological communities balanced? Are they free to move upstream and downstream? Is there an adequate food supply and breeding habitat? Are they stressed, and if so what are the stressors? A stream's inhabitants (collectively called ***biota***) are often the best indicators of overall stream health.



Traditional stream surveys focus on water quality alone. The best way to assess overall stream health is to combine water quality with physical habitat and biological integrity.

Traditional biological stream surveys typically focus on the residents of most concern to the public—gamefish such as bass and trout—and overlook most other biota. These surveys are also conducted primarily in larger streams and rivers that are likely to support gamefish. Since small streams were largely ignored, information on statewide stream conditions in Maryland has not been available until recently. It is these small streams that make up the majority of our flowing waters. Based on 1:250,000 scale maps, almost two-thirds (66%; 5,863 miles) of all non-tidal stream miles in Maryland are first order (Figures 4 and 5). It is these small streams, many of which are small enough to jump across, that often have the most intimate connection with our backyards, streets, parking lots, and farm fields. Second and third-order streams make

WHAT IS A WATERSHED?

A watershed is an area of land which drains water (and everything the water carries) to a common outlet. The critical thing to remember about watersheds is that the streams and rivers, the hills, and the bottom lands are all part of an inter-connected system. Every activity on the land, in the land, in the water or even in the air, has the potential to affect a watershed.

up about 17% (1,500 miles) and 8% (690 miles) of all non-tidal stream miles respectively. Fourth order and larger streams comprise less than one-tenth (9%; 788 miles) of all stream miles statewide.

In this chapter, we provide a snapshot of the health of Maryland's streams by describing water quality, physical habitat, and the condition of aquatic biota for first through third-order streams. We also examine some of the major stressors affecting stream health resulting from human activities. From this information, we hope to create benchmarks of current status against which we can compare stream health in the future, enabling us to document trends and evaluate the effectiveness of our stream protection and restoration efforts.

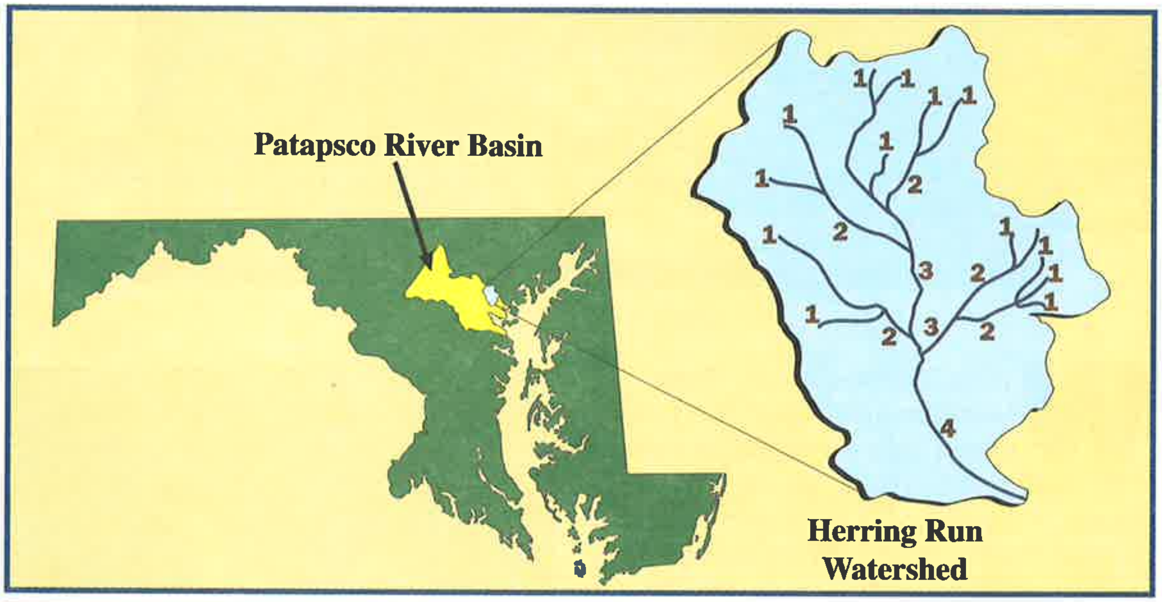


Figure 4. River basins, watersheds, and stream order. One watershed within the Patapsco River basin is that of Herring Run. The numbers beside the streams indicate each stream's order. The smallest permanently flowing stream is termed first order, and the union of two first order streams creates a second order stream. A third order stream is formed where two second order streams join.

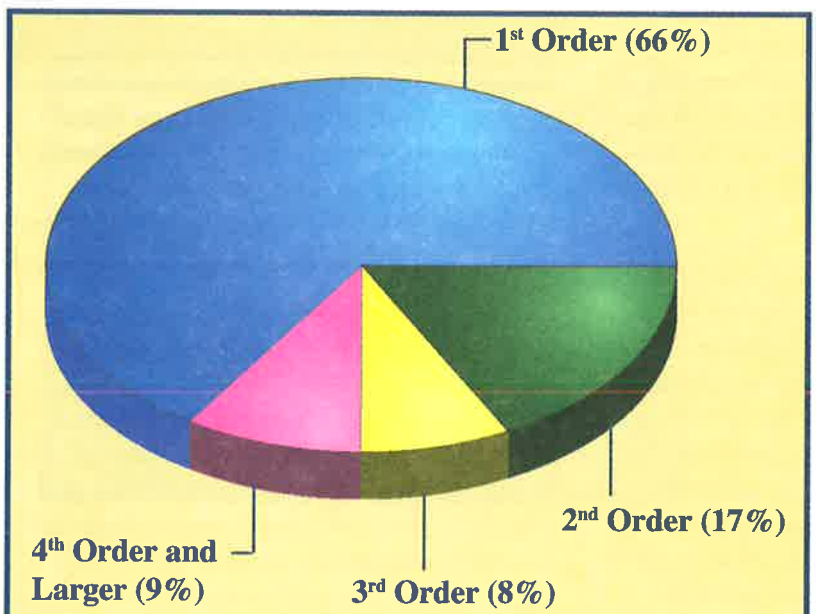
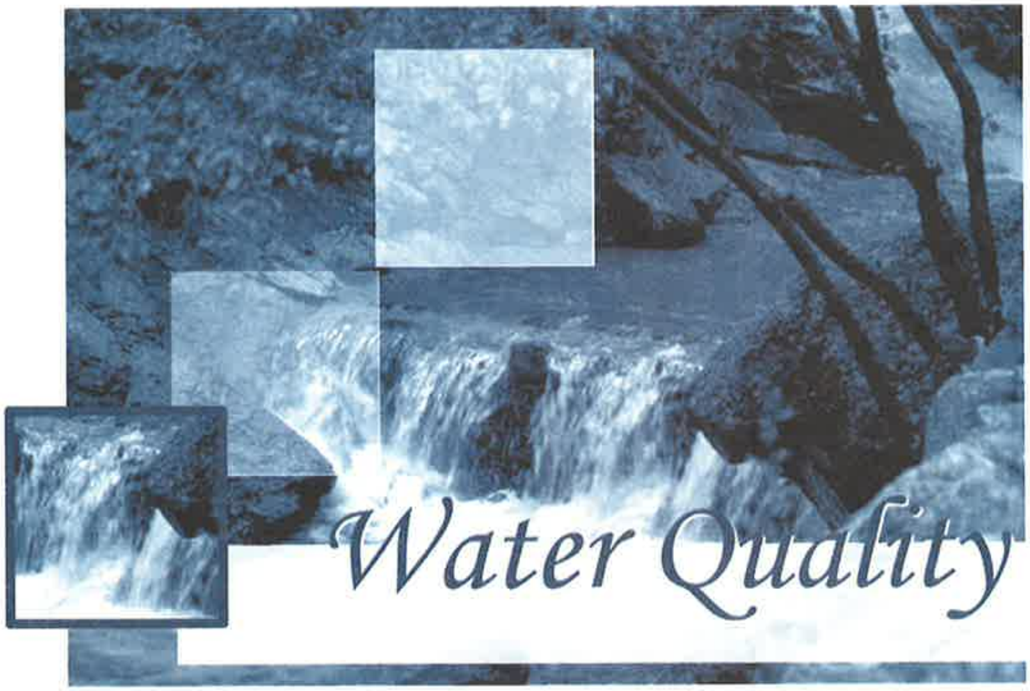


Figure 5. Maryland has over 8,800 miles of non-tidal streams. About two-thirds of these stream miles are 1st order while less than one-tenth are 4th order or larger. The average 1st order stream is less than 8 feet wide.



Many chemical and physical properties of water are important for healthy streams and healthy Marylanders. If our streams are too acidic, too warm, or overenriched with nutrients, stream biota may suffer or die. If we humans drink or swim in polluted water, our health may also suffer. Last, but not least, the future of Chesapeake Bay depends largely on the quality of the water in its streams and rivers. Because water runs downhill across the land and into streams, human activities on the land can easily impact the quality of small streams and eventually Chesapeake Bay.

This section provides an overview of pollutant sources and the quality of water in Maryland streams based on a single visit to each stream. This information about water quality, while useful, underestimates the extent of problems associated with short-term events such as heavy rains.

Nutrients

The primary and most widespread source of ***nutrients*** in streams is excess fertilizer from farm fields (Figure 6) and lawns. Nitrate-nitrogen, referred to in this report as ***nitrate***, may either run off the land during storms or soak into the ground and pollute groundwater that may take years or even decades to reach a stream. Although nutrients in sewage may impact many Maryland waterways, sewage treatment plants are often situated on larger rivers and usually do not affect small streams.

Excess nutrients enter streams in a variety of ways, including runoff of fertilizers from the land or more directly, from animal manure.
Photo by Dan Boward

Nitrate is a commonly used measure of nutrient enrichment. It is technically referred to as nitrate-nitrogen.

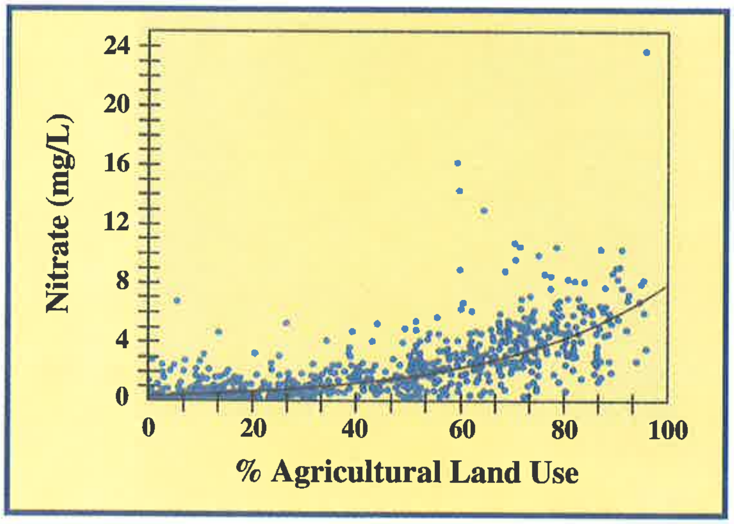


Figure 6. Stream nitrate concentrations are generally higher in watersheds with more agricultural land use. Each dot represents one Survey sampling site.

Septic systems can be a source of nitrate in rural areas and areas with low density development. Other sources of nitrate in streams include animal manure, airborne compounds in smokestack emissions, and auto exhaust.

Although excess nitrate in small streams may produce an overabundance of algae and other plants, the most devastating effect is in tidal ***embayments*** and Chesapeake Bay. Here, in combination with other nutrients such as ***phosphorus***, nitrate may contribute to ***eutrophication***.

Statewide, about 57% of all non-tidal stream miles have unnaturally elevated nitrate levels (greater than 1 mg/L) and about 2% have nitrate levels greater than 10 mg/L (Figure 7). Nitrate levels greater than 10 mg/L are above the human health standard for drinking water and are considered unsafe for human consumption. These streams are in the Nanticoke/Wicomico, Chester, Middle Potomac, and Choptank River basins.

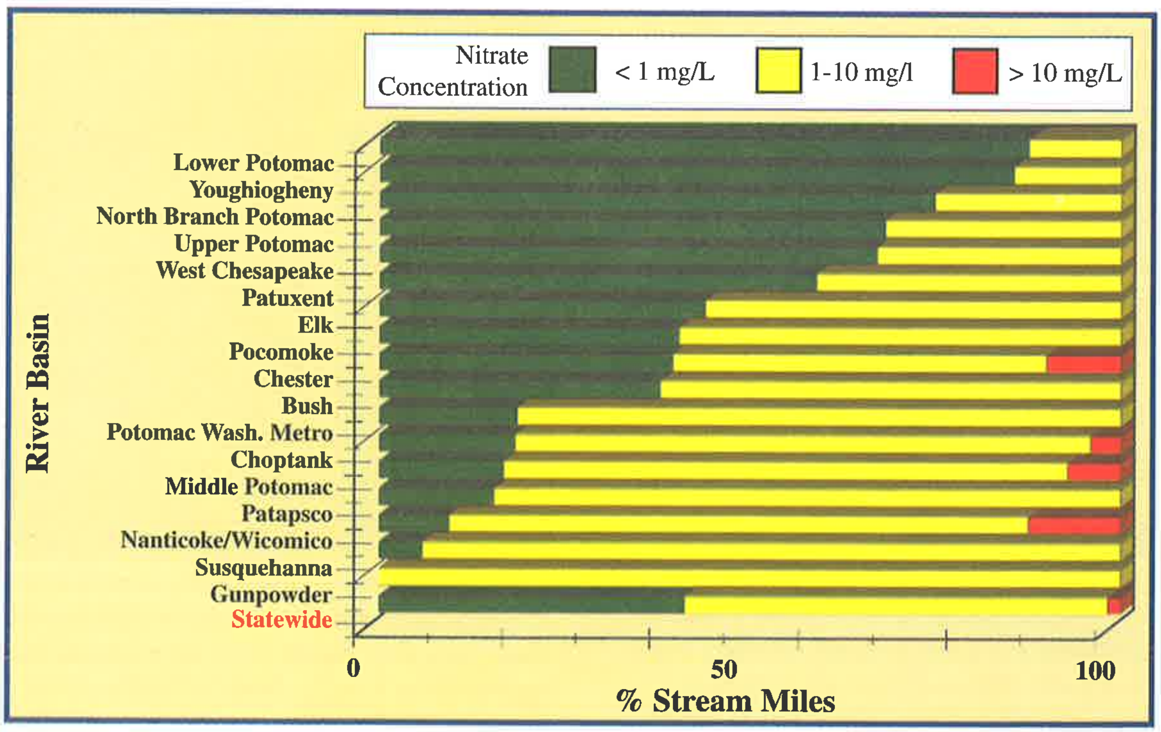


Figure 7. Streams with nitrate concentration greater than 1 mg/L are considered unnaturally high, compared to streams with minimal human influences. Concentrations greater than 10 mg/L exceed the human health standard for safe drinking water.

Acidity

Acid enters streams from four main sources: acid rain, abandoned coal mines, fertilizers, and from decomposing leaves and other natural organic material. Stream acidity is measured as ***pH***. The lower the pH, the more acidic the stream. A pH less than 5 is considered harmful to most stream biota, especially fish. When the pH of stream water is too low, gill function, egg development and larval survival are affected. Also, the concentration of metals such as aluminum become toxic to fish when runoff and stream water become acidified.

Excluding streams with substantial natural acidity, streams with pH below 5 have no fish while streams with pH above 6 have, on average, over 9,000 fish per stream mile (Figure 8) based on results of the Survey. Streams with pH between 5 and 6 have an average of only 500 fish per stream mile.

The most widespread source of acidity in Maryland streams is acid rain (Figure 9),

Smokestack emissions from factories and power plants (some as far away as Indiana) as well as car and truck exhaust contribute to acid rain in Maryland. More than 80% of all acid rain falling in Maryland comes from outside the state.

Some streams in Maryland are well-buffered and thus less susceptible to acid rain impacts. For example, many streams in the Middle and Upper Potomac river basins flow through limestone-rich soil and rocks. Their waters are

Unnatural sources of acidity are perhaps the most devastating chemical impacts that threaten Maryland stream biota.

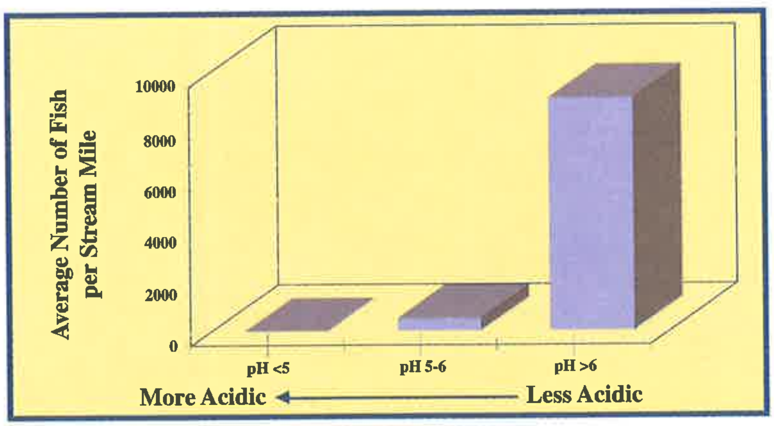


Figure 8. Low stream pH has a dramatic effect on fish. Although streams with pH between 5 and 6 contain some fish, those with pH less than 5 have none.

impacting about one in five (18%) stream miles, a length of freshwater streams about equal to the distance from Baltimore to Denver. Acid rain is formed by reactions of rain with exhaust and smoke from burnt fossil fuels such as gas, oil, and coal. Rain becomes acidic when dissolved gases form various acids, such as sulfuric and nitric acid, and fall to earth. Rain is naturally slightly acidic (pH between 5.3 and 5.7) because of its dissolved carbon dioxide content and to a lesser extent from chlorine. However, in some parts of Maryland, rain has a pH of less than 4, a level which is lethal to most stream biota.

naturally buffered by these ***alkaline*** materials. Streams in other basins are less buffered and unless the sources of acid rain are reduced, these streams may either remain acidic or one day become acidic.

Water that seeps into streams from abandoned coal mines is called ***acid mine drainage*** or AMD. These streams have a combination of low pH and high sulfate. They also commonly carry lethal levels of aluminum and high levels other metals such as iron and manganese. Since all of Maryland's coal mines (active and inactive) are restricted to the mountainous

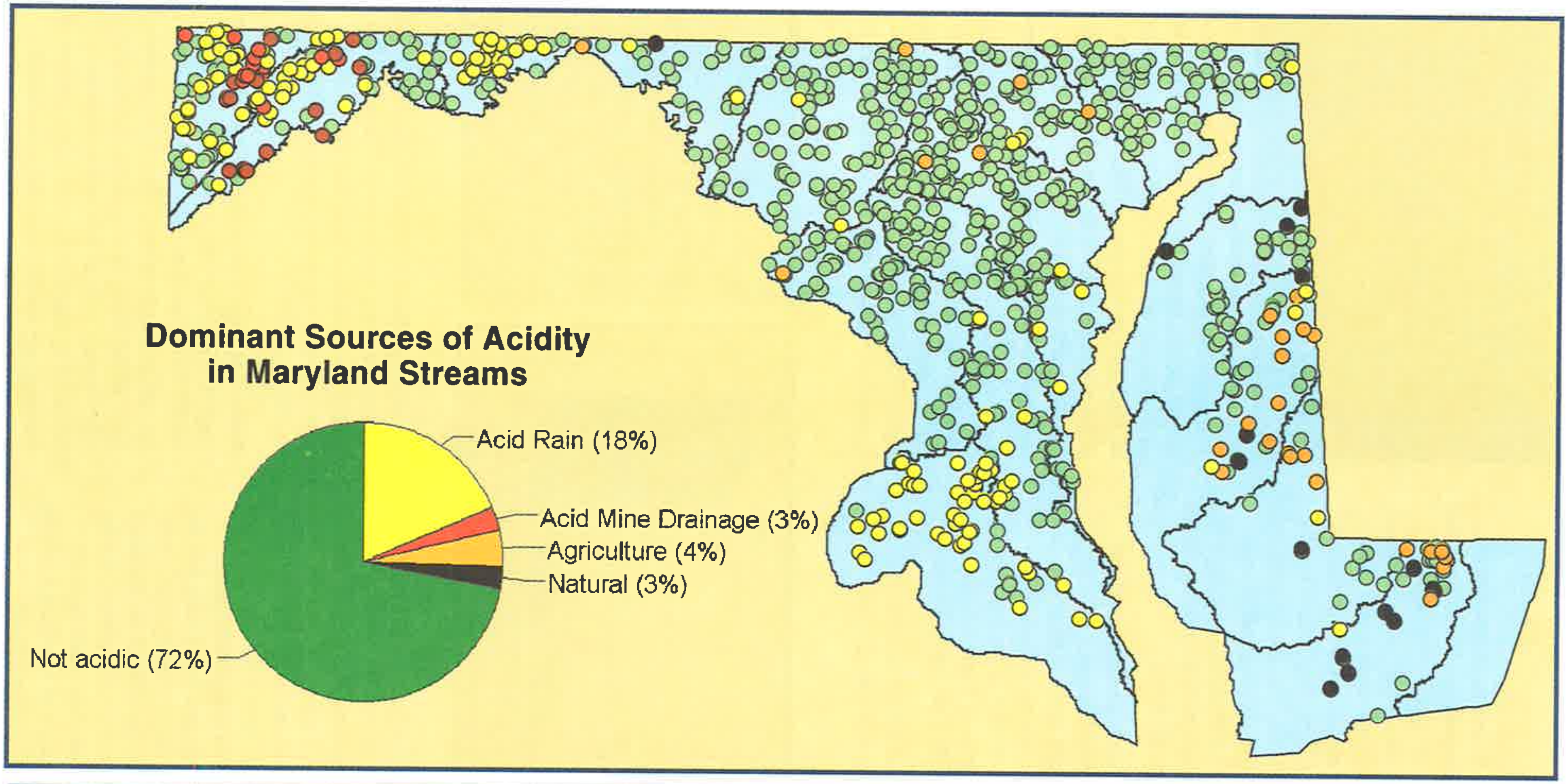


Figure 9. Acidic streams and their sources of acidity in Maryland. Acid rain is by far the most widespread source. Streams affected by acid mine drainage are restricted to the western portion of the state. Streams affected by acid rain are found throughout the state, but mostly in western and southeastern areas.

The water of an unnamed tributary to Georges Creek, in the North Branch Potomac River basin, is brownish-orange from acid mine drainage.
Photo by Scott Stranko

western part of the state, only about 3% of the total stream miles statewide are acidified by AMD (Figure 9). However, in the Youghiogheny and North Branch Potomac River basins (the two westernmost river basins in the state), AMD has acidified about 25% and 15% of the stream miles, respectively.

In some very slow moving streams of southern and eastern Maryland, leaves and other organic materials that fall into the water are not flushed away by the current and may stain the water much the way tea leaves do, resulting in brownish or blackish water. These sluggish streams have earned the name "blackwater" streams. Along with the stain, leaves also leach acids into the water and thus naturally acidify the water, but without the toxic levels of aluminum that occur in streams that are affected by acid rain and AMD.

Only about 3% of the non-tidal stream miles in Maryland are naturally acidic (Figure 9). Most are in the Chester, Choptank, Nanticoke/Wicomico, and Pocomoke river basins of the Coastal Plain. Historically, there were many more blackwater streams throughout this region, but with channelization and the extensive application of lime on farm fields for the past 100 years, the acidity of many blackwater streams is likely less today than it was historically. The biota of blackwater streams are adapted to naturally acidic conditions. They may actually be threatened by the higher pH resulting from increased buffering when farm fields are limed.

Fertilizers applied to farm fields, lawns, golf courses, and other cultivated lands that contain large amounts of nitrogen may also increase stream water acidity. About 4% of Maryland's stream miles are acidic primarily due to fertilizers. Most of these streams are on the Coastal Plain in the Choptank, Nanticoke/Wicomico, and Pocomoke river basins (Figure 9).

Zekiah Swamp Run, a blackwater swamp in the lower Potomac River Basin.
Photo by Scott Stranko

In addition to ditching and liming, the eradication of beavers from much of Maryland's Eastern Shore has reduced the number of blackwater streams. No longer held back by beaver dams and sinuous pathways, swifter stream flows now flush away the leaves that once turned the water dark brown to nearly black.

Maryland has a dissolved oxygen criterion of 5 mg/L for the protection of aquatic life.

Dissolved Oxygen

Just as sufficient oxygen is necessary for human survival, it is also critical for the survival of aquatic animals. In most swiftly flowing streams with ***riffles***, there is plenty of ***dissolved oxygen*** (DO) to support aquatic animals because the water is aerated as it flows and bubbles over rocks. However, in some sluggish, low gradient streams on the Coastal Plain, DO may drop below the state surface water criterion of 5 mg/L (or parts per million). When DO is low, only those organisms adapted to low DO levels can live. Although DO may be naturally low in many of these slow-flowing streams, nutrients in fertilizers, runoff from urban lands, and untreated sewage can act as pollutants when they trigger a series of changes that lower stream DO levels.

Statewide, 6% of all stream miles have DO levels less than 5 mg/L. But more than 25% of the stream miles in the Chester, Lower Potomac, and Pocomoke river basins have DO levels below this criterion (Figure 10). Seven river basins contained no stream miles with low DO. Because DO varies by time of day and season, the single DO sample per site taken by the Survey during the day underestimates the extent of the low DO problem in Maryland streams.

Water Temperature

Water temperature affects the health of streams in many ways. Feeding, reproduction, metabolism, and the abundance of aquatic biota may all be altered by water that is too warm or even too cold. Streams that become too warm usually contain only organisms able to tolerate the stresses of heat. Stream temperatures also affect the solubility of compounds and rate of downstream nutrient flow to Chesapeake Bay.

Runoff of heated water from impervious surfaces (such as streets, parking lots, and rooftops) is a serious and widespread problem in Maryland streams. During summer, rain that runs off of hot impervious surfaces and flows directly into streams causes temperatures to rise abruptly during storms. Even during dry periods, water temperature is usually more variable in streams draining urban lands than those draining farms and forests. Reasons for this increased variability include a reduced supply of cool groundwater and less shade than in forested streams. Constructed ponds and lakes, especially those located directly on streams, also affect stream temperature because they are sources of heated water in summer and near-freezing water in winter.

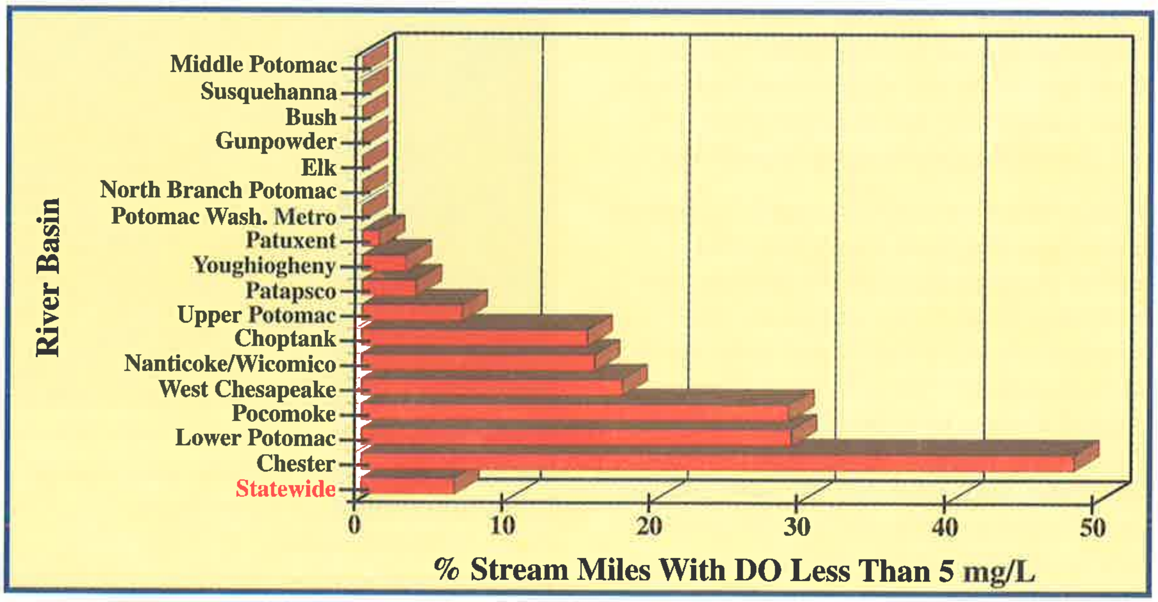
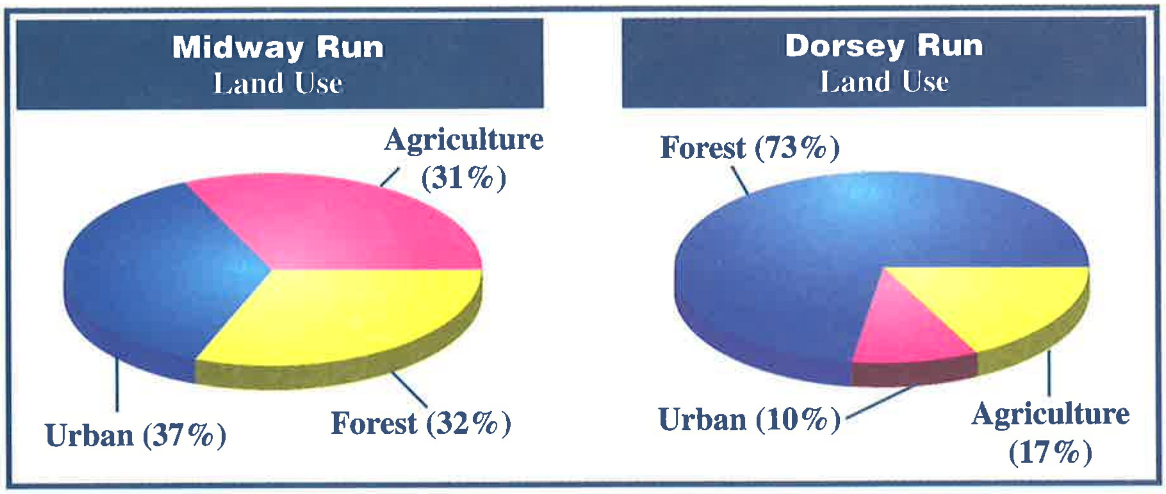


Figure 10. Percent of stream miles with less than the state water quality criterion of 5 mg/L of dissolved oxygen. Most impaired streams are in the heavily-farmed Chester and Pocomoke basins.



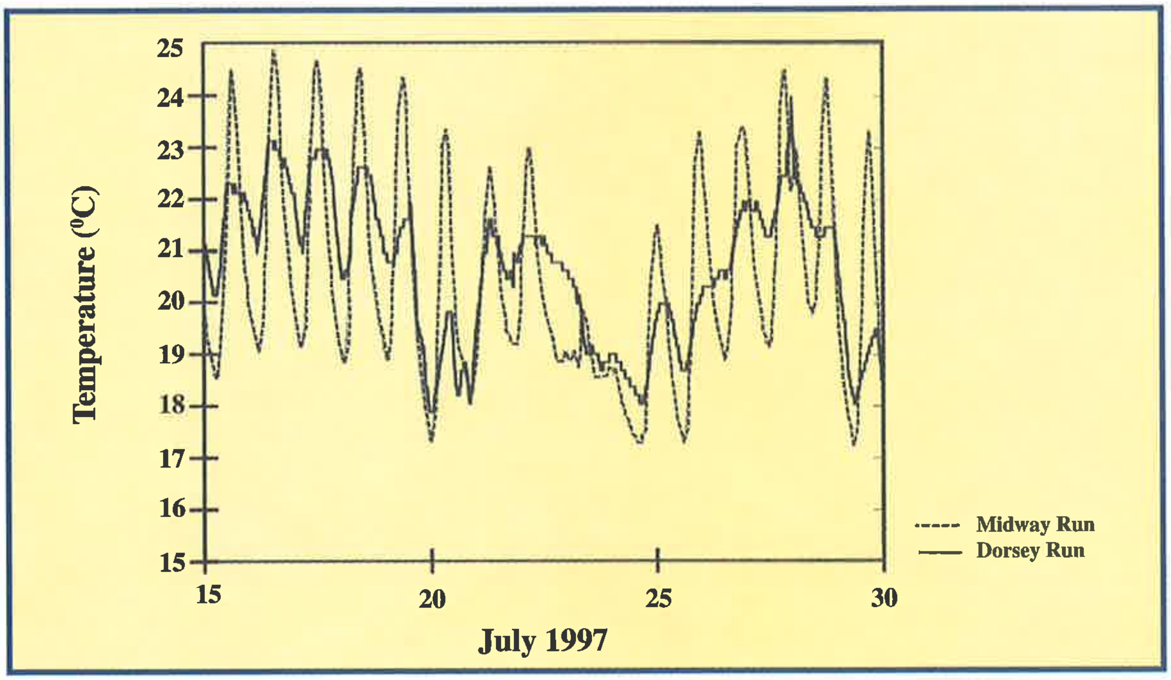
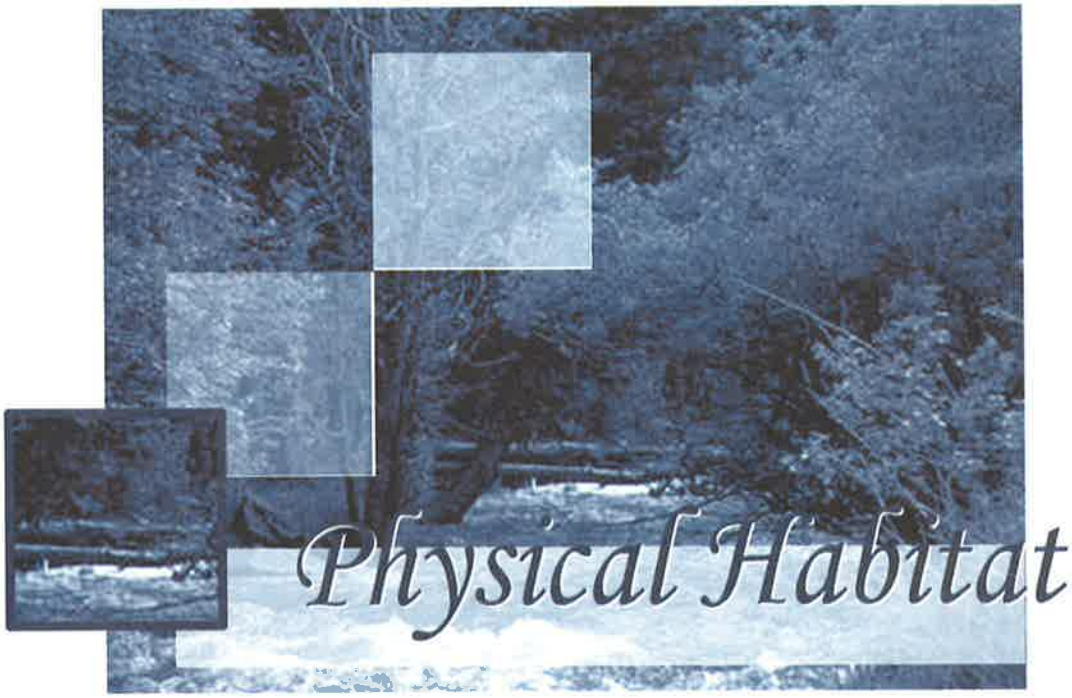


Figure 11. Water temperatures are usually lower and more stable in streams draining forested land compared to those draining urban land.

Maryland water temperature criteria for natural and stocked trout streams are 68º F (20º C) and 75º F (24º C), respectively.

During 1997, water temperature was continuously monitored during summer at about 200 Survey sites in 5 river basins. Although statewide information on stream temperature is currently not available from the Survey, two streams sampled in 1997 in the Patuxent River basin—Dorsey Run and Midway Run—provide some insight into water temperature differences in streams with different upstream land uses. Both are second-order Coastal Plain streams with similar widths and depths at the sampling sites, but different upstream land uses. Dorsey Run's watershed is mostly forested (73%), with only 10% urban land use. The remainder of its watershed (17%) is agricultural. Midway Run's watershed, however, is fairly evenly split among forest (32%), urban (37%), and agricultural (31%) land use.

In July, the water in Midway Run became warmer in the daytime (and cooler at night) than that in Dorsey Run (Figure 11). Also, the highest daytime temperatures were reached more quickly in Midway Run relative to Dorsey Run. Had an afternoon thunderstorm occurred during the period, the differences would have been even more pronounced. The comparison between these two watersheds gives us insight into how the loss of natural land cover (forest), increase in the amount of upstream impervious cover, increase in runoff temperature, and reduced ***baseflow*** adversely affect water quality and aquatic biota.



Physical Habitat

In addition to clean water, physical habitat is critical for healthy streams. In general, good stream habitats have: 1) wide, naturally vegetated ***riparian buffers***, 2) ***meandering*** channels with stable, naturally vegetated banks, 3) a variety of ***substrate*** types (such as wood, roots, and rocks), and 4) a variety of water depths and water velocities. Unfortunately, humans have altered natural stream habitats throughout Maryland, affecting both water quality and aquatic life.

Riparian Zone

FUNCTIONS OF VEGETATED RIPARIAN BUFFERS

1) Reduce dramatic fluctuations in stream temperature
2) Reduce nutrient and ***sediment*** runoff
3) Stabilize stream banks
4) Provide organic matter for stream food webs
5) Provide ***migration corridors*** and nesting areas for many terrestrial species
6) Supply wood and roots for channel formation and habitat

The riparian zone is the area along the bank of a stream, river, or other water body. Vegetated riparian zones may act as a buffer against pollution and are therefore very important in mitigating the adverse impacts of human activities. Although there are several buffer types, forested riparian buffers provide the best stream protection. Streamside forests provide shade, helping to keep streams cool and dampening fluctuations in stream temperature. They provide structures such as wood and roots that improve habitat and stabilize channels. Like other vegetated buffers, streamside forests also reduce nutrient and sediment runoff, stabilize stream banks, and provide organic matter that can be used by aquatic animals. Wide forested riparian buffers protect streams from runoff and generally provide better habitat for plants and animals than narrow buffers. Protecting and restoring forested riparian buffers on small streams is critical since small streams receive most of their flow from runoff and groundwater while larger streams receive most of their flow from upstream tributaries that may be poorly buffered.

Statewide, about 59% of all stream miles have forested riparian buffers (Figure 12). About 40% of the forested stream miles statewide have buffers greater than 50 meters (164 feet) wide (Figure 13). Almost 60% of the stream miles in the Lower Potomac, North Branch

WHAT IS HABITAT?

The theater in which the ecological play takes place; it is a template for the biota, their interactions, and their evolution.

About 25% of all stream miles in Maryland lack a vegetated riparian zone and thus are unbuffered against stormwater runoff.

The *duff* on streamside forest floors and the soil beneath it act as a sponge, slowing runoff of nutrients, sediment, and toxic compounds into streams.
Photo by Ken Yetman

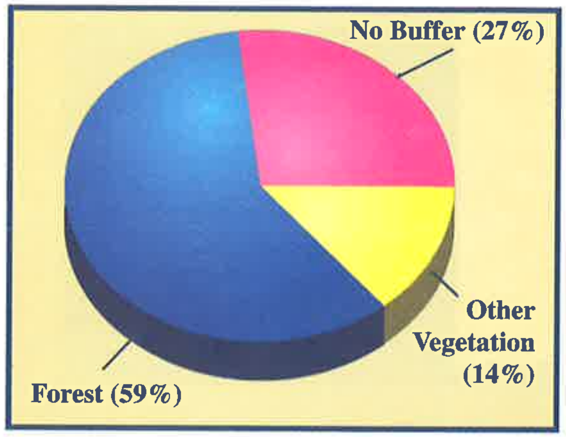


Figure 12. More than half of all stream miles in Maryland have forested riparian buffers while just over one-quarter are unbuffered against runoff.

Twenty-seven percent of all stream miles in Maryland have no vegetated riparian buffer.

Potomac, Upper Potomac, and West Chesapeake basins have wide forested buffers. In contrast, the Middle Potomac, Pocomoke, and Patapsco basins each have fewer than one-quarter of all stream miles bordered by wide forested buffers. More than one-quarter (27%) of all stream miles in the state are unbuffered and 14% are buffered by vegetation other than forest, such as abandoned cropland or lawns.

Wood in Streams

Another widespread impact to stream physical habitat quality in Maryland is the loss or removal of wood, such as logs, limbs, and roots, along stream banks and in stream channels. Destruction of riparian forests, stream ***channelization***, and the removal of fallen trees from streams all contribute to this

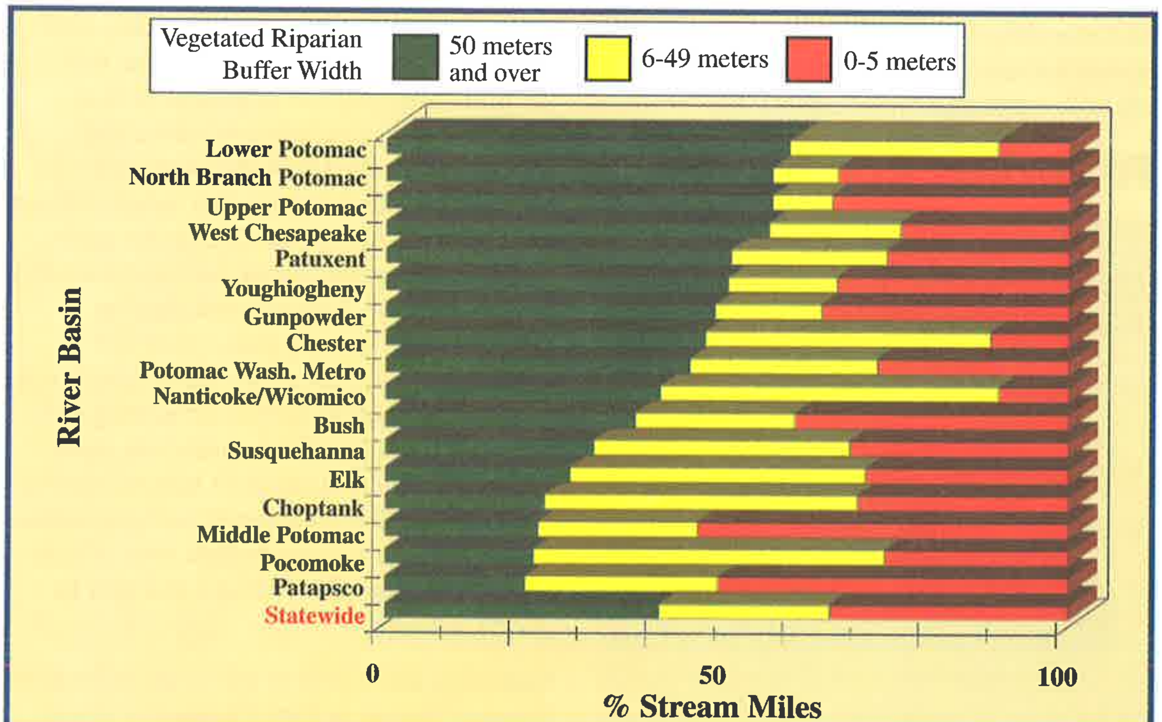


Figure 13. Forty percent of Maryland's stream miles are adequately buffered (green shading) by riparian vegetation (trees, shrubs, grass), 25% are only moderately buffered (yellow shading), and 35% have either narrow buffers or none at all (red shading).

Wood in streams enhances habitat quality in many ways.
Photo by Brian Stranko

degradation. In many streams, particularly in the Coastal Plain, wood provides a diverse array of stable habitats and cover for stream animals. Limbs and roots also trap leaves, a vital food supply for many ***benthic macroinvertebrates***. Undisturbed streams in naturally-forested areas generally contain a great deal of wood. Without these natural structures, banks may become unstable and erode, contributing to sediment and nutrient pollution in downstream rivers and the Chesapeake Bay.

During the Survey, sampling crews noted the number of logs, large tree limbs, and tree roots at each sample site. Among all river basins in Maryland, counts of wood per stream mile range from 40 in the Upper Potomac to 220 in the Chester basin. The statewide average is 91 (Figure 14). Coastal Plain streams, such as those in the Chester and Choptank basins, tend to have more wood than streams outside the Coastal Plain, although these numbers are likely much lower than they were historically. Higher velocities in the steeper gradient streams outside the Coastal Plain may flush wood from the channel more quickly than in the more sluggish streams of the Coastal Plain.

Channelization

As much of Maryland changed from forested to developed land, many streams were channelized to drain farm fields or allow for efficient movement of ***stormwater*** from urban lands. In many areas of the state, channelization causes the most severe physical habitat impacts to streams. During channelization, naturally meandering streams are straightened,

WOOD IS GOOD

In streams that drain farm fields, large limbs and tree trunks are often removed to keep the water flowing. This practice generally decreases habitat quality for fish and aquatic invertebrates.

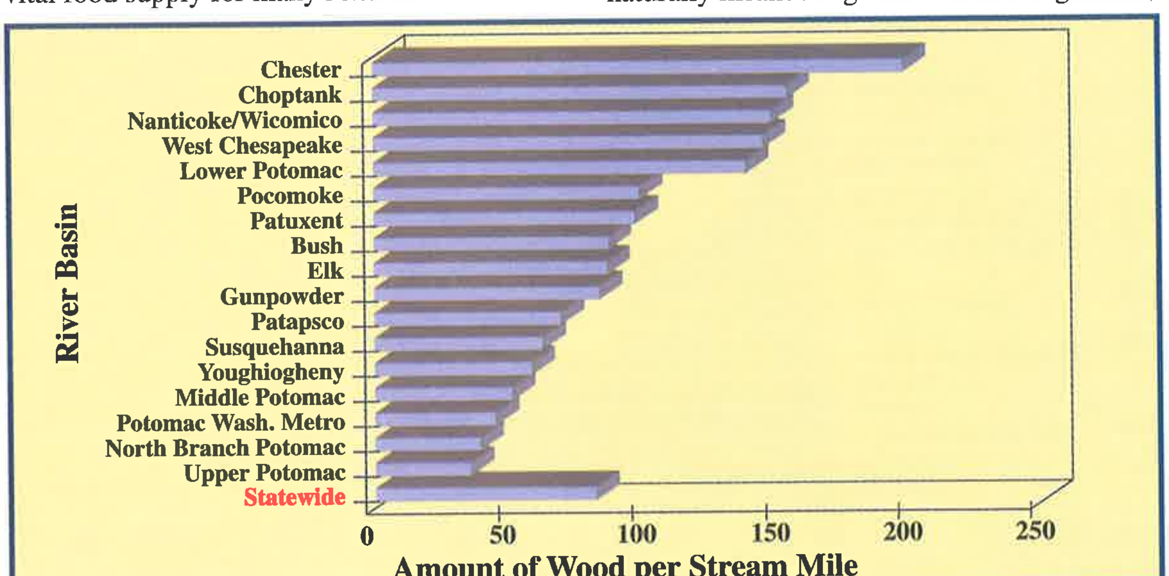


Figure 14. Coastal Plain streams tend to have more wood, roots, and limbs than those outside the Coastal Plain. These structures provide valuable habitat for stream animals.

Stream channelization is more prevalent in agricultural areas containing wetlands.

Stream channelization comes in many forms. Along farmland (above) many streams are stripped of their riparian vegetation and straightened. In urban areas (right), they are often lined with concrete. *Photos by Niles Primrose (above) and Dan Boward (right)*

riparian vegetation is often cut, and wood is removed from the stream. Fortunately, many streams in agricultural areas that were channelized a century or more ago are now beginning to revert to a more natural state. This may be reflected in the higher amounts of wood in streams of the Coastal Plain, described above. The most extreme habitat impacts come in urban areas when streams are converted to concrete-lined ditches that provide minimal habitat for only the hardiest aquatic biota. With straightened channels and less obstructed flows, channelization also increases the speed at which nutrients and sediment flush from upland streams to downstream rivers and Chesapeake Bay.

About 17% of all stream miles statewide are channelized (Figure 15). More than one-half of the stream miles are channelized in two

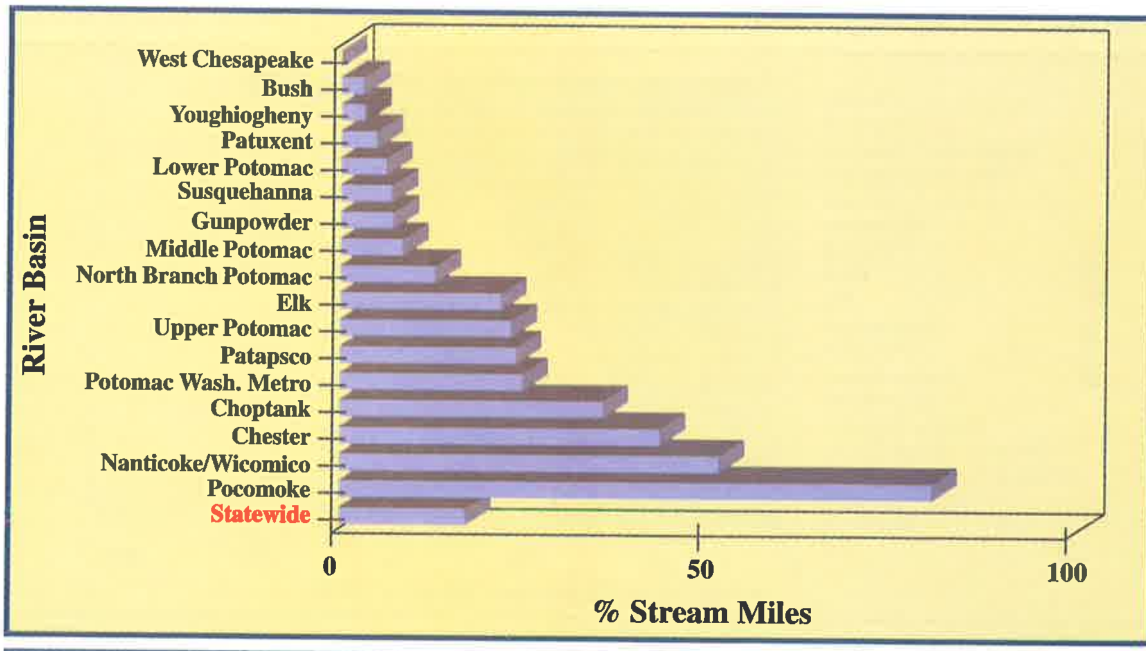


Figure 15. Stream channelization in Maryland is more prevalent in the Coastal Plain and in the heavily urbanized central part of the state.

heavily farmed river basins on the Eastern Shore: the Pocomoke and Nanticoke/ Wicomico. Because both basins contain many wetlands, which are not suitable for farming, channelizing streams here to produce ***arable land*** was more common than in other basins. About one-quarter of all stream miles in the Patapsco and Potomac Washington Metro basins are channelized, primarily to drain the expansive impervious areas in and near Baltimore and the District of Columbia.

Bank Stability

Excessive stream bank erosion is one sign of poor physical habitat with both near and far-reaching consequences. Natural stream banks are stabilized with tree roots, logs, rocks or other materials that minimize erosion even during floods. Soil from eroding banks becomes sediment that is moved by the current and coats the stream bottom, reducing available habitat for benthic macroinvertebrates and spawning areas for fish. Excess sediment in the stream channel also causes bank erosion farther downstream. This same sediment clouds the water, smothers aquatic plants, clogs the gills of aquatic animals, and carries nutrients contributing to eutrophication in Chesapeake Bay.

Thirty percent of all stream miles statewide have good bank stability (Figure 16). More than two-thirds of the stream miles in the two westernmost basins, the North Branch Potomac and Youghiogheny, have good bank stability. In contrast, almost three quarters (75%) of all stream miles in both the Gunpowder and Patuxent basins have poor bank conditions. Streambanks in Western Maryland may be naturally more stable than those to the east because rocks (boulders and bedrock) are more prevalent in and along stream channels

Bank erosion is often most severe where there is little vegetated riparian buffer and few roots to hold the soil.
Photo by Dan Boward

About one-half of all stream miles in Maryland have unstable stream banks.

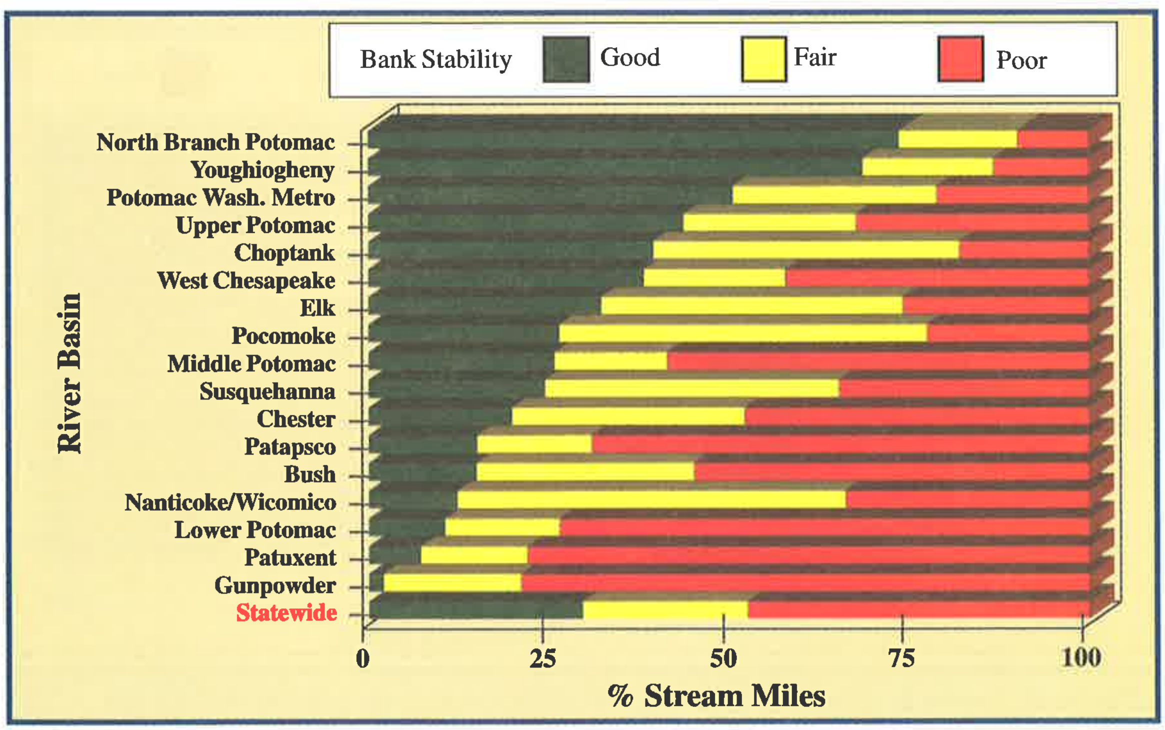


Figure 16. Streams in the western part of Maryland tend to have more stable banks than those in the east. Erosion from unstable banks contributes to downstream sedimentation problems in larger rivers and Chesapeake Bay.

in the west, and thus provide more stability for stream banks. But in urban areas, such as portions of the Patuxent and Gunpowder basins, stream channelization and elevated flows during storms may dramatically increase bank erosion, especially where banks are not well armored by stable structures such as wood and rocks.

Overall Physical Habitat Quality

Although we may gain insight into specific physical habitat problems by examining one habitat measure at a time, it is useful to combine these measures (e.g., riffle/run quality and instream habitat) to assess the overall physical habitat condition of a stream.

DNR recently developed a provisional index to evaluate physical habitat conditions in non-tidal Maryland streams. By comparing various physical characteristics of one stream to the characteristics of least impaired streams, the Physical Habitat Index (PHI) generates a score that rates the overall physical habitat quality of the sampled stream segment.

The Physical Habitat Index incorporates several measures of habitat quality into one easily understood number.

Based on the provisional Physical Habitat Index (PHI) developed for the Survey, about 20% of all stream miles in the state are in good condition, while 52% are poor (Figure 17). More than three-quarters of all stream miles in the West Chesapeake and Nanticoke/Wicomico basins are in poor condition. In contrast, the Elk and Susquehanna basins had the lowest percentages (11% and 25%, respectively) of stream miles rated poor for physical habitat quality.

Although the PHI scores should be considered preliminary, our results suggest that physical habitat degradation is an important, widespread problem in Maryland streams. Because riparian buffer zones are such an important attribute of streams and rivers, riparian forests should be staunchly protected. Replanting protective vegetation along streams with adequate riparian buffers is an obvious starting point in the restoration process that should eventually increase PHI scores. Long-term stream monitoring programs should accompany all restoration efforts to evaluate their success.

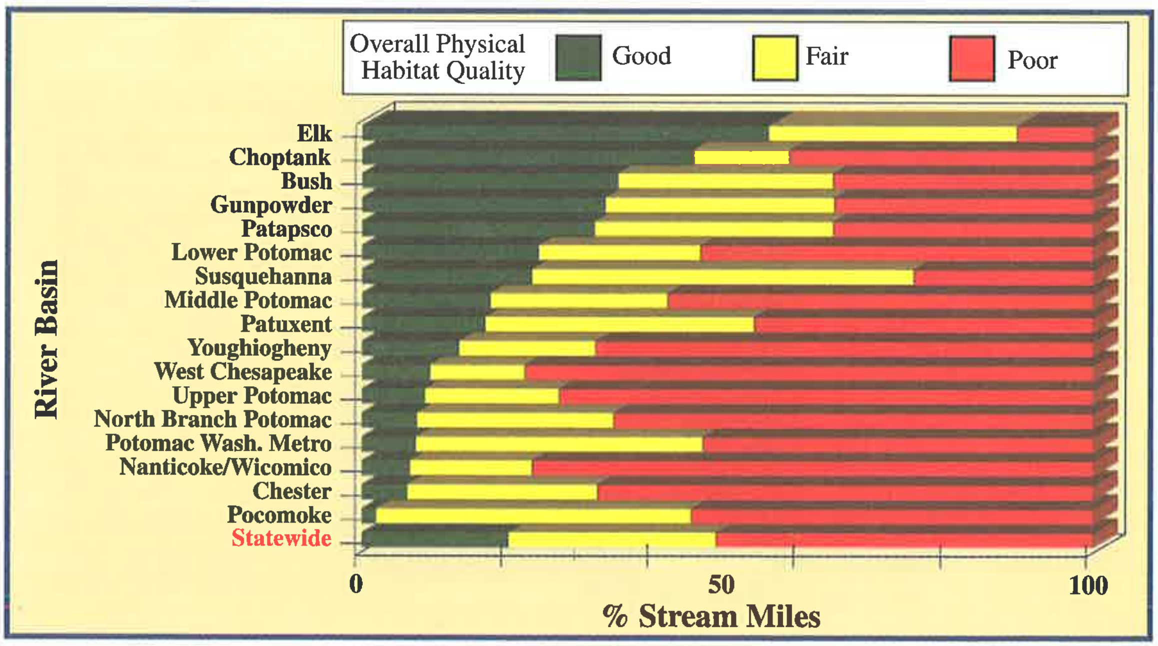


Figure 17. Statewide, about one-fifth of the stream miles are rated good by the Physical Habitat Index while a little over half are rated poor. The Elk River basin contains the highest percentage of stream miles rated good by this Index. More than one-half the stream miles are rated poor in 11 of the 17 basins.

Reptiles and Amphibians

Amphibians and reptiles (collectively called ***herpetofauna***, or herps) are excellent indicators of stream and watershed health. Because many of these animals live part of their lives in water and part on land, their survival depends not only on water quality but also on the physical make-up of both environments.

Forty-five species of herps were found statewide during the Survey, and 9 out of 10 stream miles harbor at least one species. Of these 45 species, 29 are either aquatic or intimately dependent upon riparian environments. In general, fewer herp species live in or near Coastal Plain streams than elsewhere in the state. The number of species per basin ranges from 28 in the Patuxent River basin to 10 in the Nanticoke/Wicomico and Bush basins (Figure 18).

Although several herp species are sensitive to acid rain and other water quality impacts, results from the Survey suggest that, in Maryland, urbanization has a larger impact on herp species diversity, with fewer species occurring in more urbanized areas. Only seven of the 29 aquatic or riparian species were found at sites where watershed imperviousness exceeded 25%, while 22 species occurred at less urbanized sites (Figure 19). Four species of salamanders occurred exclusively at sites within the least urbanized watersheds (<3% impervious land cover).

Black Rat Snake
Photo by Paul Kazyak

The amount of urban land in a watershed influences which reptiles and amphibians can live in its streams. A number of species can not tolerate the sometimes harsh conditions found in urban streams.

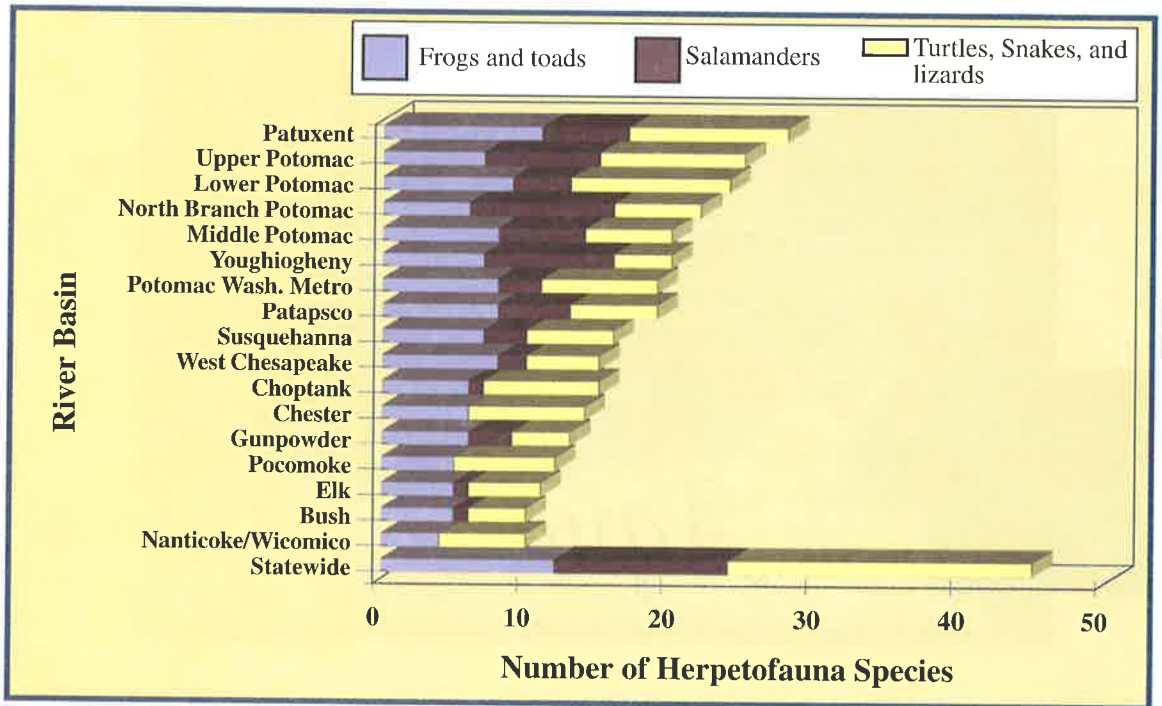


Figure 18. Forty-five species of herpetofauna were found during the Survey. No salamanders were found in the Chester, Pocomoke, or Nanticoke/Wicomico river basins.

Mountain dusky, seal, Jefferson, and northern slimy salamanders were never found in urbanized watersheds with more than 3% impervious land cover.

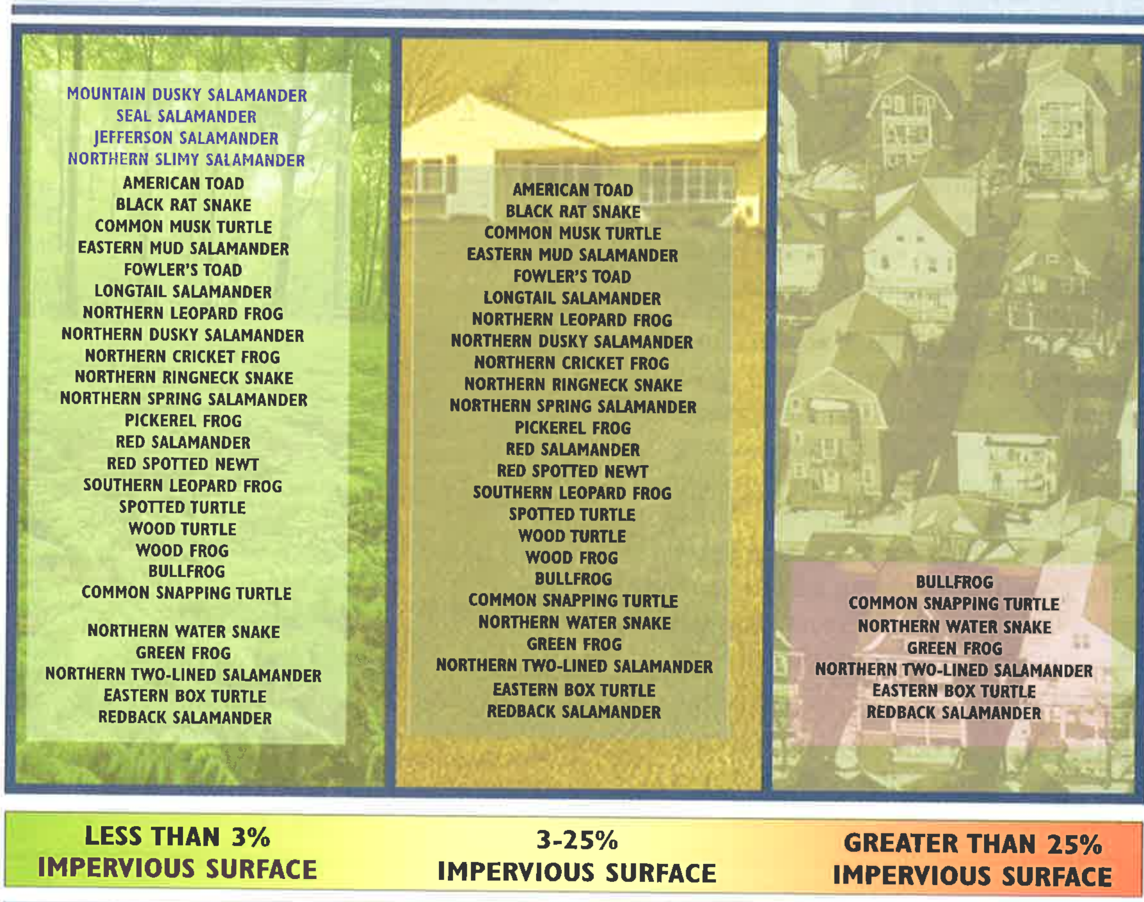


Figure 19. Of the 29 aquatic or riparian species of herpetofauna found during the Survey, only 7 occurred in heavily-urbanized areas (>25% impervious land cover in the upstream watershed). Conversely, 4 species of salamanders (in blue) never occurred in urbanized areas (>3% impervious land cover).

Fish

General Description

Maryland's streams are home to a diverse array of native fishes that are often unnoticed by most stream observers. Numbering more than 100 species, the total population of Maryland stream fish exceeds 61 million. From tiny and reclusive shiners to big and brash catfish, these animals are key components of balanced stream ecosystems. Because many fish consume benthic macroinvertebrates, aquatic plants, or detritus, and are themselves eaten by larger fish, they provide an integral link in stream food chains.

Maryland's stream fish are exposed to many physical and chemical stressors, including stream channelization, dams, toxic contaminants, introduced species, and acid rain. Because they often show a range of tolerance to stream degradation, fish communities are good indicators of overall stream health. These communities include many species that are unfamiliar to most of us, but are nonetheless a vital part of our stream ecosystems. The Survey provides us with both basic information on fish communities in our streams (that can serve as a baseline for future assessments) and a way to examine how stressors affect both fish communities and individual fish species.

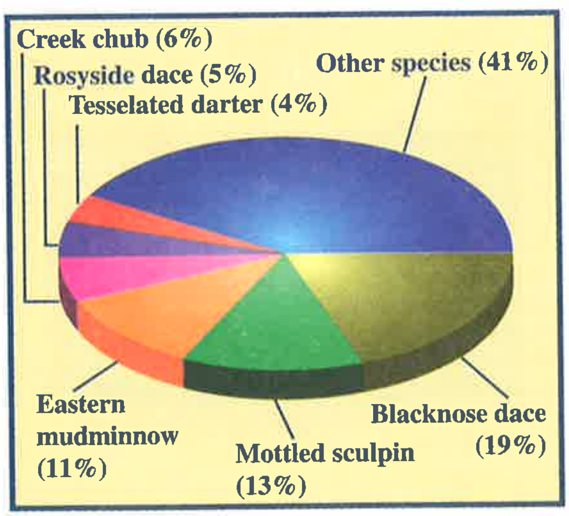


Figure 20. Of the approximately 61 million fish in Maryland's streams, the pollution-tolerant blacknose dace is the most abundant.

Rosyside dace
Photo by Brian Stranko

The most abundant (19%) fish in Maryland's streams is the pollution-tolerant blacknose dace (Figure 20). Other common species include the pollution-tolerant eastern mudminnow and creek chub, moderately pollution-tolerant mottled sculpin and tesselated darter, and pollution-intolerant rosyside dace.

Introduced Fish

Introduced (sometimes called non-native or exotic) fish species are a common occurrence in Maryland's streams. As far back as the 1870s, habitat destruction and overharvest depleted native fish populations to the point that the only viable alternative to sustaining recreational fisheries was thought to be the introduction of new species. In the last 125 years, many species have been stocked in an effort to boost the variety and quality of fishing opportunities in Maryland waters. Some, such as the popular largemouth bass and not-so-popular common carp, have been

Goldfish.
Photo by Bob Lunsford

There are about 12 times as many stream-dwelling fish in Maryland as there are people. Of all these fish, only 3% are gamefish—those most familiar to us.

highly successful in adapting to Maryland's environment. Other non-natives have entered Maryland streams via other, less intentional means, such as from angler bait buckets and release of aquarium pets.

About 20 species of introduced fish live in Maryland's streams. Some of the species not native to all or most of the state include: goldfish, fathead minnow, green sunfish, channel catfish, bluegill, brown trout, rainbow trout, largemouth bass, and smallmouth bass. Almost one-half (45%) of the stream miles statewide have at least one introduced fish (Figure 21). In general, river basins on the Eastern Shore have more introduced fish per stream mile than basins in other areas of Maryland. About three-quarters of the stream miles in the Elk and Choptank basins have introduced fishes, while less than one-quarter of the stream miles in the North Branch Potomac and Upper Potomac basins contain them. Because most introduced fish species in Maryland streams are adapted to life in large streams and rivers, they are less likely to be found in small streams (Figure 22).

Almost one in two stream miles in Maryland now harbors at least one introduced (non-native) fish species.

Because many studies have shown that introduced species can reduce or even eliminate native species through competition and predation, proposals to introduce non-native fish in new areas are now subject to careful review and consideration before action is taken. This approach should help to minimize adverse effects on our native fauna in the future.

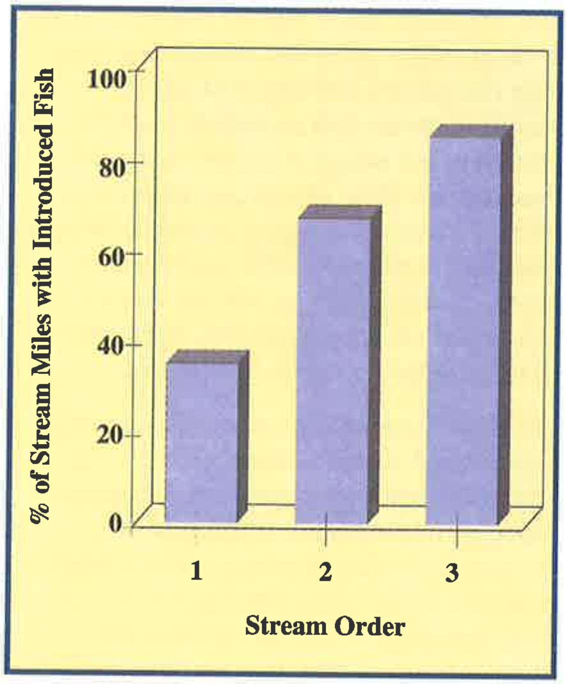


Figure 22. Throughout Maryland, introduced fish occur more than twice as often in 3rd order streams than in 1st order streams.

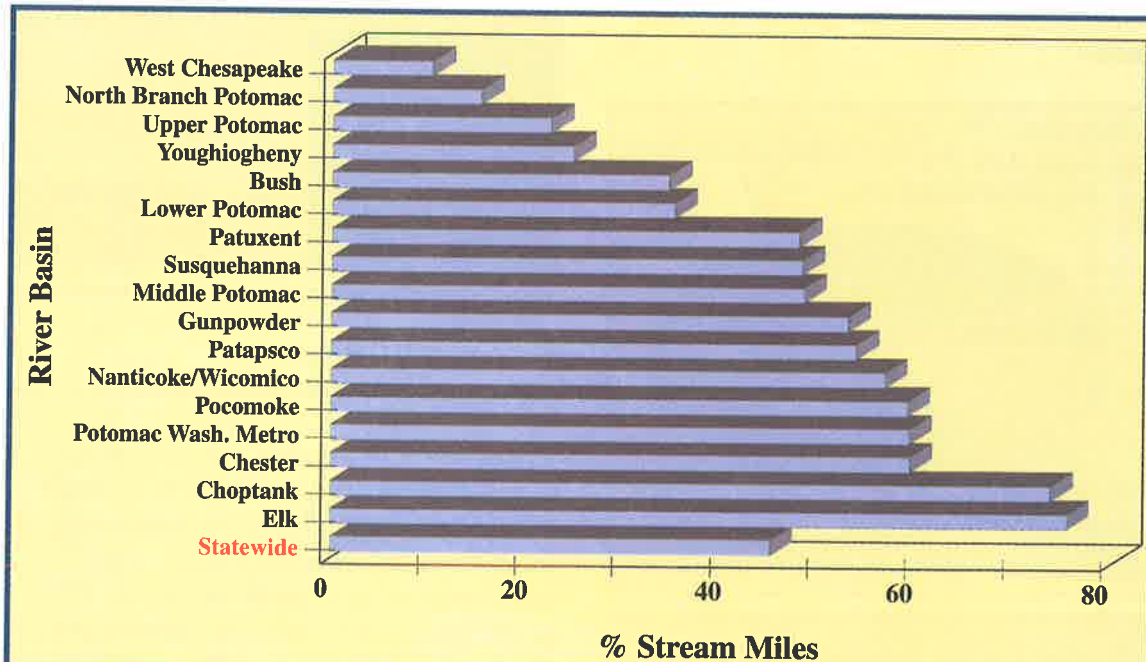


Figure 21. Almost half of Maryland's stream miles have introduced fish. They are generally more common in Coastal Plain streams, especially on the Eastern Shore.

A Tale of Two Natives

Once numbering more than 3 million, only about 300,000 brook trout now live in Maryland streams. Today, brook trout are found in scattered portions of the Piedmont (Patapsco, Gunpowder, Bush, and Lower Susquehanna basins) and the Allegheny Plateau (North Branch Potomac and Youghiogheny basins) (Figure 23). No brook trout were found in the Coastal Plain during the Survey, although they are known to occur in Jabez Branch, a tributary to the Severn River in the West Chesapeake basin.

Brook Trout
Photo by Paul Kazyak

Although reasons for the decrease in brook trout are many, one of the most important factors may be water temperature. As trees were cleared for agriculture and housing, previously forested streams were exposed to direct sunlight as well as hot water runoff from impervious surfaces like roads and rooftops (Figure 24) and warm water discharges from ponds and lakes. Today, fewer and fewer streams are cool enough to support brook trout, particularly in the eastern half of the state. In addition to impervious surfaces, other major threats to the continued existence of brook trout in Maryland include silt from new construction and agriculture, competition from non-native brown trout, loss of forests along streams, acid rain, acid mine drainage, and global warming.

The story of American eel in Maryland streams is much like that of brook trout. Since the time of European settlement, distributions of this species have changed in response to impacts to their migratory routes. Early settlers built many small dams to supply water power for mills. Later, more dams were added for water supply, flood control, and hydroelectric projects, and additional barriers were created during road construction. Today, there are more than 1,000 man-made barriers to migratory fish in Maryland (Figure 25), and

Two native Marylanders, brook trout and American eel, were once abundant and widespread in our streams.

Brook trout were never found in streams with greater than 2% impervious land cover in the upstream watershed.

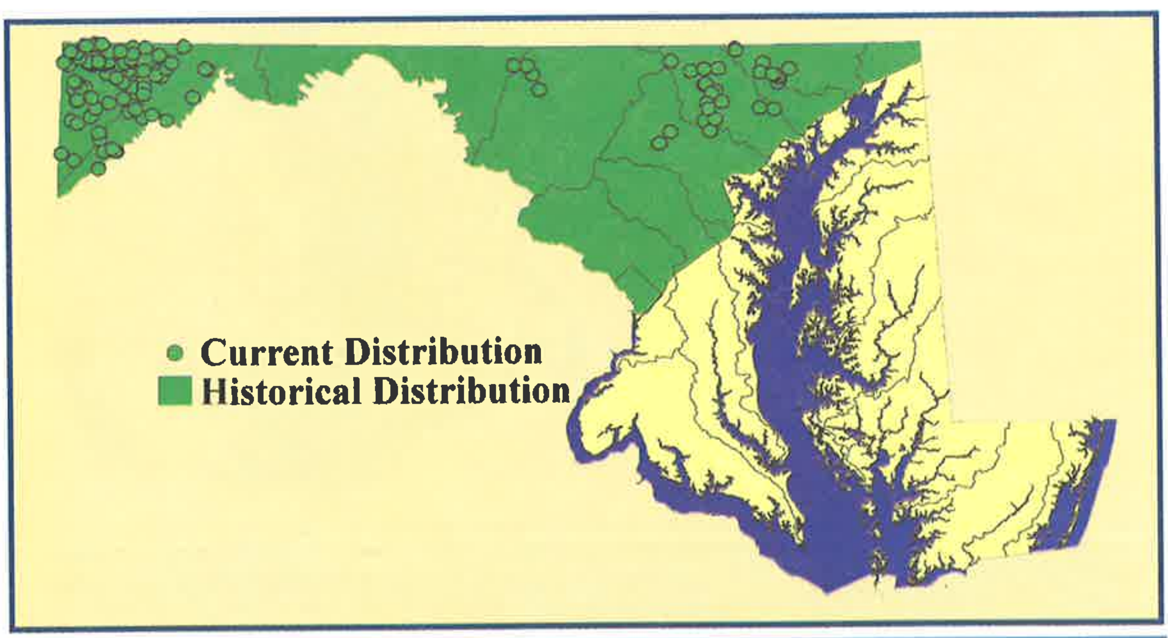


Figure 23. Historically, brook trout ranged from the Fall Line to the western border of the state. Current distributions (Survey sites with brook trout) are limited to portions of central and western Maryland.

DID YOU KNOW?

American eels may live up to 30 years. The oldest one on record was 85! Eels do not become definitely male or female until they are about 10 inches long.

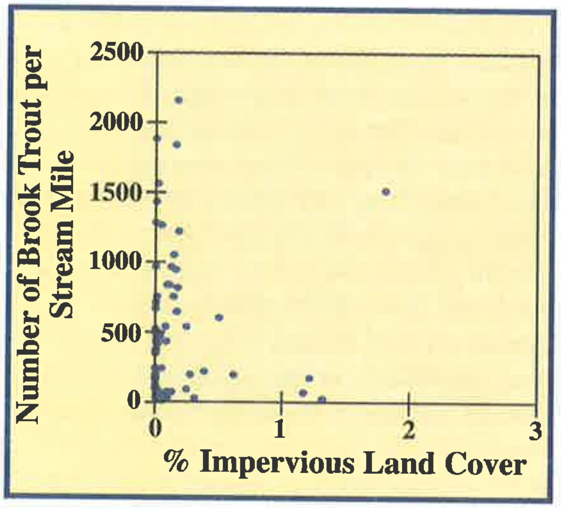
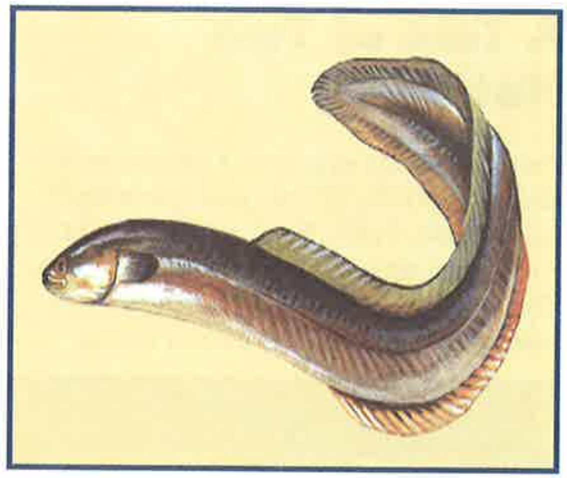


Figure 24. Brook trout are extremely sensitive to the amount of roads, rooftops, and other impervious land cover in a watershed.



Spawning in the depths of the Atlantic Ocean, many American eels migrate to small freshwater streams in Maryland where they mature and spend much of their adult lives.

access to historical spawning and nursery habitat has been greatly reduced for many fish species in addition to eels.

An example of the decline of American eel abundance resulting from dam construction can be found in the lower Susquehanna River. Prior to the completion of Conowingo Dam in 1928, the annual harvest of eels in the river was nearly 1 million pounds. Since then, the annual harvest has been zero—eels have all but disappeared above the dam (Figure 26). Even in areas without migration barriers, widespread loss of habitat continues to limit eel abundance in Maryland streams. The results of the Survey make it clear that additional efforts will be necessary if we are to protect the living heritage of brook trout and American eel for future generations.

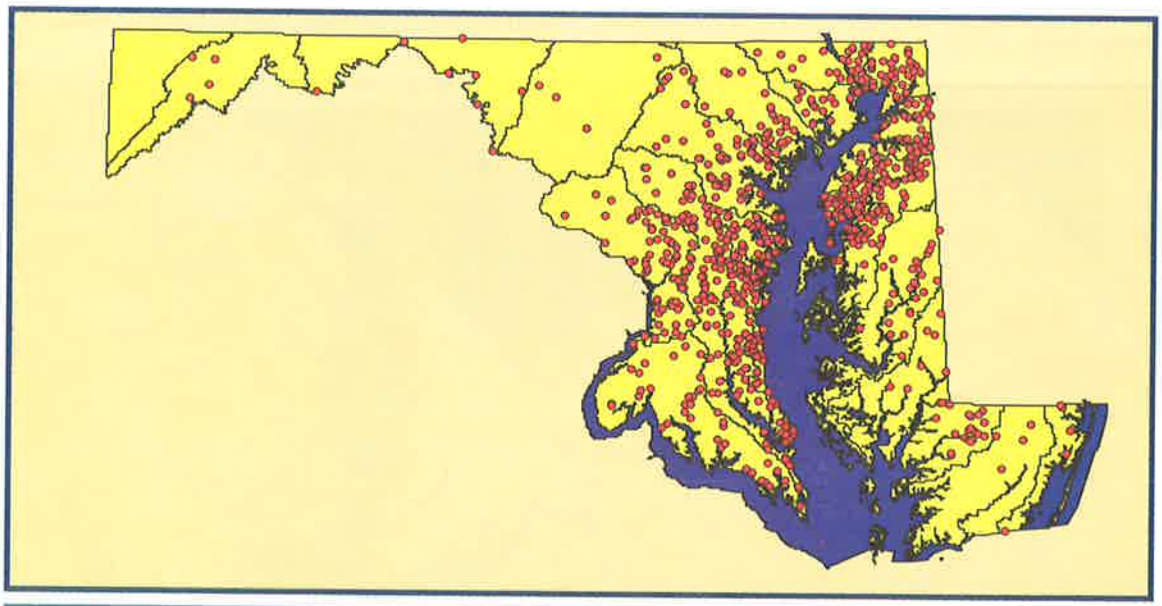


Figure 25. There are more than 1,000 known blockages to fish migration on Maryland's streams, including dams, culverts, pipe crossings, and gabions. Most documented blockages are east of the Fall Line and prevent migratory (anadromous and catadromous) fish from migrating upstream from Chesapeake Bay to points west. These blockages are the initial focus of DNR's fish passage program. Once passage has been restored at these blockages, DNR will focus its efforts on blockages in the western part of Maryland.

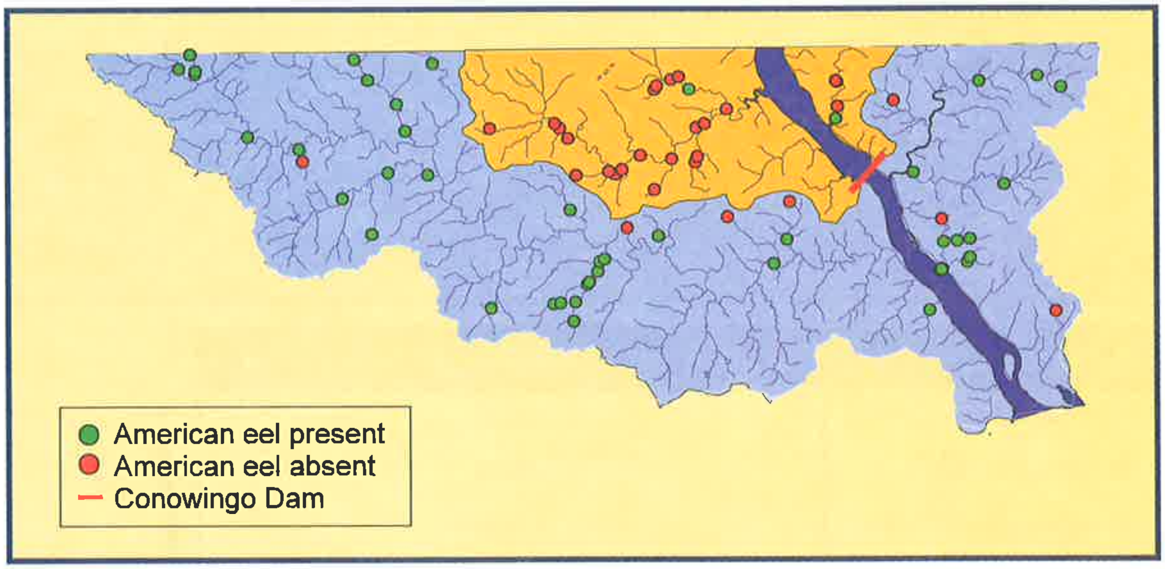


Figure 26. Conowingo Dam blocks the migration of American eel. During the Survey, eels were found at only two sites upstream of the dam. Because they must swim through the dam's hydroelectric turbines to return to the sea as mature adults, eels that manage to pass through Conwingo dam may be injured or killed and unable to complete their life cycle.

Rare, Threatened, and Endangered Fish Species

Maryland darters are small, inconspicuous bottom-dwelling fish, federally listed as endangered. They were last observed in the Deer Creek watershed (Lower Susquehanna River basin) in 1987 and are believed to be extinct. A restriction of their range may have occurred with the completion of the Conowingo Dam on the Susquehanna River in 1928. Siltation and water withdrawl for drinking and irrigation are considered to be the principal threats to the last known population.
Photo by Jim Williams

The Endangered Species Act of 1973 classifies a species as either endangered when it is in danger of extinction within the foreseeable future, or threatened when a species is likely to become endangered if its numbers continue to dwindle. Maryland has several classifications of rare species that vary according to a species' distribution, estimated number of populations, and their viability.

Over the past few decades, there has been increased concern among scientists, natural resource managers, and the public over the loss of native plant and animal species locally, regionally, and world wide. Although species extinction is a natural phenomenon, it has increased dramatically in the last century as a result of human activities. While newspaper stories often tell of extinctions in far away places such as tropical rain forests, the streams in our own backyards contain plants and animals that also need our attention and protection. Rapid, uncontrolled development, acid rain, and a host of other human influences contribute to the widespread loss of habitat vital to stream dwellers. Concern for many of these species is not new. Federal and state

Table 2. Rare and endangered Maryland fish species based on the Survey and listed by Maryland DNR. There are about 500,000 pearl dace in Maryland. This may seem like quite a few compared to stripeback darter (<600). Why are pearl dace considered rare if there are so many? In Maryland, pearl dace are found only in streams draining to Antietam Creek and Marsh Run in the Upper Potomac River basin. Because this rare species literally has all its eggs in just a few baskets, it is highly vulnerable to stream degradation.

Species	Estimated Number in Maryland	
Rainbow darter	< 600	Each of these species occur in less than 0.5% of Maryland's streams
Stripeback darter[S1]	< 600	
Banded darter	< 600	
Flier[SU]	1,500	
Ironcolor shiner[S1]	3,000	
Comely shiner	3,500	
Glassy darter[S1, E]	5,000	
Logperch[S1]	8,000	
Striped shiner	10,000	
Johnny darter	80,000	
American brook lamprey	180,000	Each of these species occur in less than 5% of Maryland's streams
Mud sunfish[S2]	3,500	
Swamp darter	10,000	
Warmouth	25,000	
Silverjaw minnow	60,000	
Shield darter	75,000	
Banded sunfish	80,000	
Brook trout	320,000	
Checkered sculpin	475,000	
Pearl dace	500,000	

Notes on current listings

- [E] Endangered in Maryland
- [S1] Extremely rare in Maryland
- [S2] Rare in Maryland
- [S3] Uncommon in Maryland
- [SU] Rare-uncertain status in Maryland

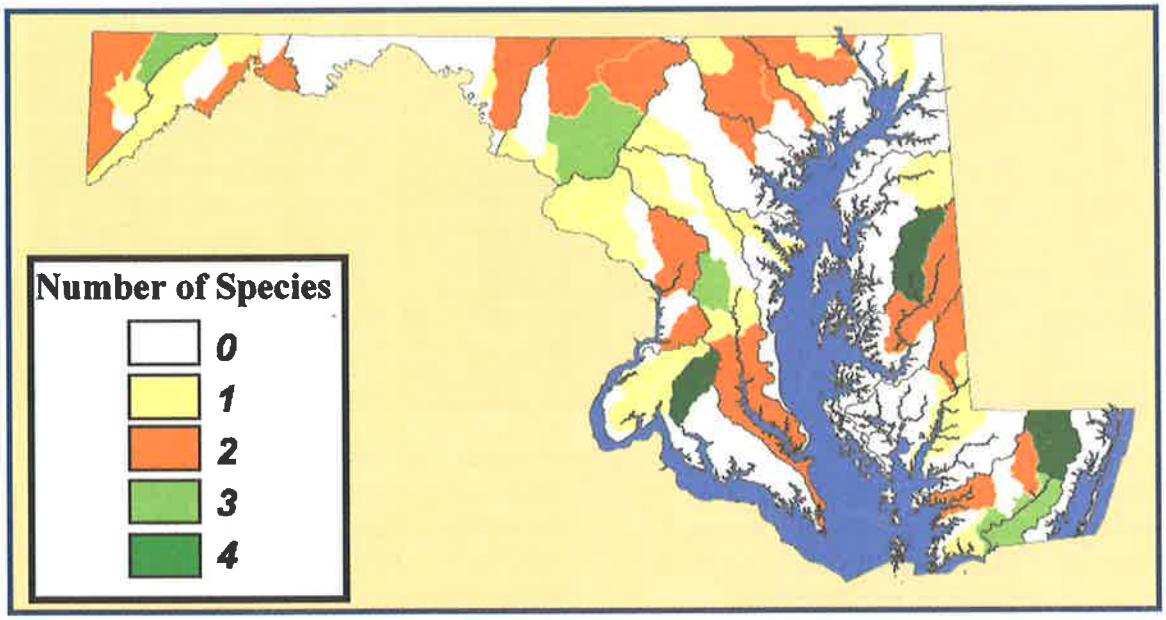


Figure 27. Distribution of rare and endangered fish species in Maryland. Watersheds, described on page 51 of the Technical Appendix, are shaded by the number of species found by the Survey.

agencies may classify species as rare, threatened, or endangered, and focus programs (e.g., protection and restoration) on them.

In Maryland, we are faced with the potential loss of several fish species, a situation that often goes unnoticed until it is too late. Results of the Survey support the current state listings of stripeback darter and glassy darter and show that other species (e.g., flier, ironcolor shiner, glassy darter, logperch, and mud sunfish) may also warrant listing (Table 2). Populations of these animals are either alarmingly low, or they are restricted to the few areas where habitat quality is still favorable. Unfortunately, some species like the federally endangered Maryland darter were not found at all by the Survey and may be extinct.

Although state-listed rare and endangered fish are found in several watersheds throughout Maryland, some areas, like Zekiah swamp in the Lower Potomac basin, Tuckahoe Creek in the Choptank basin, and the Upper Pocomoke River, have up to four such species in their watersheds (Figure 27). Watersheds of the Casselman River in the Youghiogheny basin, Lower Monocacy River in the Middle Potomac basin, Western Branch of the Patuxent River, and the Lower Pocomoke River contain up to three rare, threatened or endangered fish species each. No federally listed threatened or endangered fish species were found by the Survey.

Benthic Macroinvertebrates

Benthic macroinvertebrates, or more simply "***benthos***," are animals without backbones that are larger than a pinhead. These animals live

Predatory hellgrammites live under large rocks in swiftly-moving streams.
Photo courtesy of the North American Benthological Society.

There over 350 types (taxa) of benthic macroinvertebrates in Maryland streams.

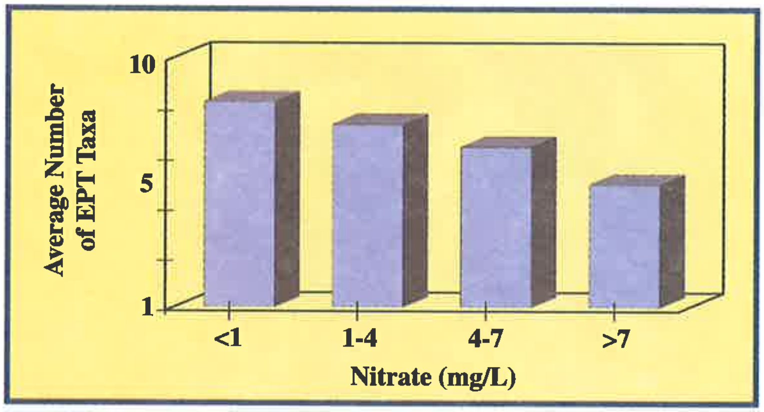


Figure 28. The average number of sensitive benthic macroinvertebrate taxa (EPT taxa) declines with increased nitrate concentration. Streams with nitrate <1 mg/L are considered to have natural nitrate levels.

in streams on rocks, logs, leaves, aquatic plants, or in soft sediments. The benthos include crayfish, clams and snails, aquatic worms, and aquatic insects such as mayflies, stoneflies, caddisflies, and dragonflies.

Why use benthos to evaluate stream health? Unlike fish, benthos are fairly immobile, so they are less able to escape the effects of excess ***sediment*** and other pollutants that degrade water quality. Thus, the benthos can give us reliable information on water and habitat quality in streams. They represent an extremely diverse group of aquatic animals with a wide range of tolerances to pollutants. Also, many benthos live for several years, allowing detection of past environmental problems.

Because benthic macroinvertebrates are found in almost every Maryland stream and are easy to catch with inexpensive equipment, several volunteer monitoring groups use them as indicators of stream health.

And the winner is...

Of all sites sampled in the Survey, Buffalo Run in the Youghiogheny River basin had the highest diversity with 37 benthic macroinvertebrate taxa. The watershed upstream of this second order stream in Garrett County was mostly forested (67%), with some agriculture (33%). Conversely, Moores Run in the Patapsco River basin (Baltimore City) had only one taxon. This second order stream drains a mostly urban (83%) watershed.

The number of pollution-sensitive benthic macroinvertebrate ***taxa*** may be used to indicate stream health. Many mayflies, stoneflies, and caddisflies are generally sensitive to water quality and/or physical habitat degradation. These three groups are collectively referred to as EPT, from their taxonomic order names Ephemeroptera, Plecoptera, and Trichoptera. These animals are often the first to be eliminated from a stream once it is polluted or the physical habitat degrades.

The number of EPT taxa can provide some insight into water quality impacts from, for example, point source discharges or runoff from urban or agricultural land that add nitrate and other nutrients to Maryland streams. The average number of EPT taxa found during the Survey declined with increased nitrate concentration (Figure 28).

The presence or absence of certain benthic macroinvertebrate taxa can also help us pinpoint potential stressors in streams. For example, the stonefly *Acroneuria* is pollution-sensitive and survives only among clean rocks in streams with cool, swiftly-moving water and a good amount of dissolved oxygen. In the Middle Potomac River basin, which is mostly agricultural land, these insects were found at only 9 of the 109 sites sampled and primarily in the heavily-forested mountains in the western part of the basin (Figure 29). Streams here are likely to be less polluted by sediment, nutrients, pesticides, and herbicides that often enter streams in runoff from agricultural areas. However, the more pollution-tolerant black fly, *Prosimulium,* was found throughout the basin—in forested, agricultural, and urban watersheds. These insects can live in degraded streams in the more developed areas of the basin.

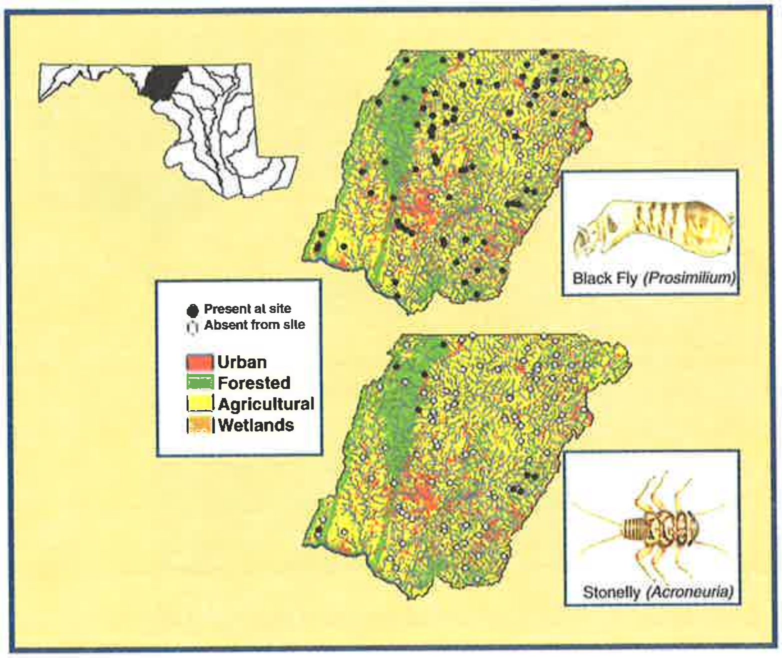


Figure 29. In the Middle Potomac basin, pollution-sensitive stoneflies were found primarily in forested areas while pollution-tolerant black flies were found in all areas of the basin.

The Index of Biotic Integrity provides us with an overall picture of stream health by quantifying the condition of fish and benthic macroinvertebrate communities.

Index of Biotic Integrity

Although we can evaluate individual aspects of stream health, such as the presence or absence of rare, threatened, or endangered fish species, or the number of pollution-sensitive benthic macroinvertebrates, it is quite useful to combine several measures of stream community health into one overall value, or index. By using an index, complex ecological information can be summarized and stream health can be rated as either good, fair, or poor.

One such index of the overall health of stream communities is the ***Index of Biotic Integrity***, or IBI. Benthic macroinvertebrate and fish IBIs developed for the Survey reflect the structure and function of these communities as compared to reference (healthiest) streams within a similar region. Streams rated good or fair by the IBIs are considered healthy compared to the reference streams. Good streams are comparable to the highest quality reference streams and fair streams are comparable to the remainder of the reference streams. Poor streams are considered unhealthy compared to reference streams. These Indices have several measures or metrics that describe, for example, the number of species (a measure of community structure), the feeding mode (a measure of community function), pollution sensitivity, and proportion of introduced species, and thus provide us with a picture of overall ecological stream health. The EPT Index, described in the preceding section, is one component of the benthic macroinvertebrate IBI. See the Technical Appendix for a more detailed explanation of the fish and benthic IBIs.

Based on the benthic macroinvertebrate IBI, only 11% of all non-tidal stream miles in Maryland are in good condition, while just over half (51%) are in poor condition (Figure 30). This index rates the remaining stream miles (38%) as fair. The fish IBI paints a somewhat different picture of the health of Maryland streams. One-fifth (20%) of all stream miles are rated good, almost one-third (29%) are rated poor, and 26% of the stream miles are rated fair by the fish IBI. Because benthic macroinvertebrates and fish have different pollution sensitivities, habitat requirements, and abilities to avoid pollution, it is reasonable to expect that these two IBIs may not always agree at the same stream site.

By combining the benthic and fish IBIs, we get a more integrated picture of overall stream health as measured by both aquatic communities. For all non-tidal stream miles in Maryland, the provisional Combined Biotic Index (CBI) rates almost one-half (46%) of all stream miles poor, 42% fair, and 12% good (Figure 31). Using this combined Index, the Potomac Washington Metro basin has the smallest percentage of stream miles rated good (<1%) while the Bush has the highest percentage in this category (25%).

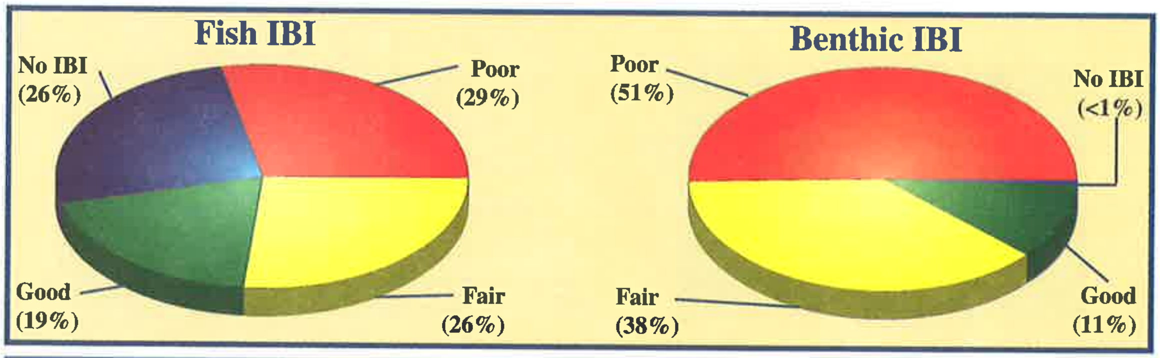


Figure 30. The health of Maryland's streams as indicated by the fish and benthic macroinvertebrate Indices of Biotic Integrity (IBIs). Fewer stream miles are rated good and more stream miles are rated poor by the benthic IBI. Fish IBIs were not calculated for small streams (watershed upstream <300 acres) while benthic IBIs were not calculated for streams with very low subsample sizes (<60 organisms).

Urbanization is perhaps the greatest stressor to the biota of Maryland streams. As noted in the brook trout example on page 37, the impacts from urbanization to stream habitats and water quality are often so severe that even minimal amounts cause degradation and loss of resources. This fact is supported by the relationship between the percent of impervious land cover upstream of Survey sample sites and the CBI (Figure 32). When watershed imperviousness exceeds 15%, stream quality was never rated good, thus illustrating one of the natural resource benefits of focusing growth into areas that are already urbanized and limiting the amount of impervious land cover throughout the state.

The Future of Maryland's Streams

As we look ahead to the future of Maryland streams, it is critical to reflect on the past and evaluate the present. Although we are moving in the right direction in many ways, such as controlling non-point source runoff, point source discharges, and providing passage to

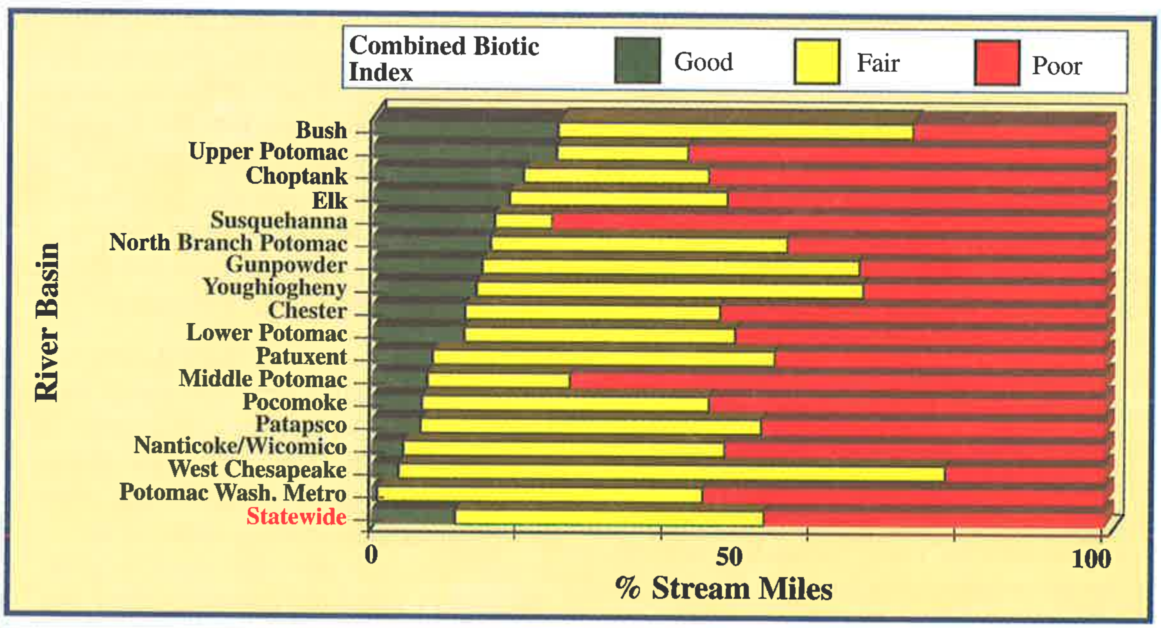


Figure 31. The provisional Combined Biotic Index (CBI) provides a picture of stream health based on both benthic and fish communities. Statewide, almost one-half of all stream miles are in poor condition based on this Index.

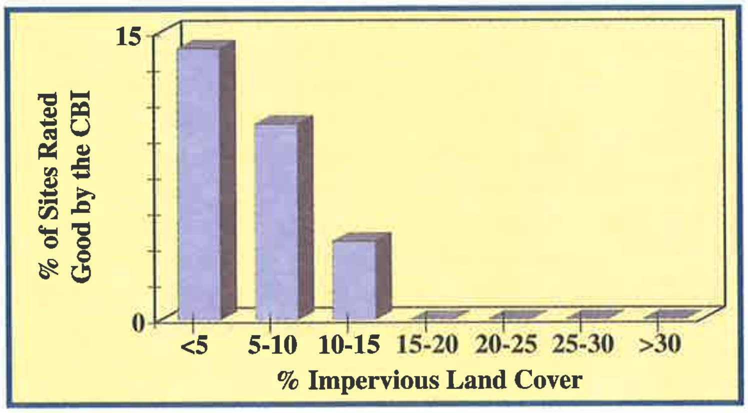


Figure 32. The amount of impervious land cover upstream of a stream site influences the Combined Biotic Index (CBI), a biological measure of stream health. When watershed imperviousness exceeds 15%, stream health was never rated good.

Water is the most critical resource issue of our lifetime and our children's lifetime. The health of our waters is the principal measure of how we live on the land.
— Luna Leopold

migratory fish, human activities continue to impact Maryland streams, Chesapeake Bay, and, although often ignored, even the Gulf of Mexico. Fish communities are unhealthy in

Youghiogheny River Gorge
Photo courtesy of MD DNR

more than a quarter of our stream miles, while more than half of all stream miles have benthic macroinvertebrate communities in poor condition.

Beyond the community level, 7 of the 100 or so freshwater fish species in Maryland are afforded special protection because they are in danger of extinction and an additional 15 species appear to be at similar levels of risk. When individual river basins are considered, the number of populations that may be threatened or endangered grows even larger. American eel and brook trout, once abundant in Maryland streams, are now restricted in number and distribution. Clearly, there is much work ahead if we are to save our remaining resources and attempt to restore some of what we have lost.

More than one-third of our stream miles have little or no vegetated riparian buffers. While there is increasing interest in protecting and reestablishing riparian buffers, forested areas along streams continue to be lost, even on public lands. Although achieving Maryland's goal of 600 additional miles of forested stream buffers by the year 2010 (Maryland's *Stream Releaf Program*) will be a landmark achievement, much more needs to be done. We also need to recognize the vital importance of allowing trees that die naturally to fall into streams, where they create more habitat in those streams and rivers that already have forested riparian buffers.

Conversion of farmland and forest into urban areas continues at a rapid pace in Maryland. At the current rate of population growth and development, an area the size of Baltimore County (612 square miles or about 5% of Maryland's total area) will be urbanized in the next 25 years. The old adage that "an ounce of prevention is worth a pound of cure" is especially appropriate when considering the effects of urbanization—we now know that living resources in streams are impacted even at low levels of urbanization and that these impacts become pronounced when the amount of impervious land cover exceeds 15% of a watershed. Another problem is population growth. With the projected rate of population increase in Maryland, many streams in the state will become more degraded by the cumulative impacts of too many people.

The future health of many Maryland streams will be dependent on our commitment to redirect population growth and development into existing urban areas rather than continue to "sprawl" into forested and agricultural areas. Streams that are currently healthy should be protected—the most cost-effective strategy. But, for those streams that have been degraded by urbanization, intense agricultural practices, acid mine drainage, or acid rain, some level of restoration may be needed.

Restoration includes a broad range of management actions designed to help streams recover and function at a self-sustaining level. The first and most important step in a restoration action is to halt, wherever possible, the disturbance that is causing degradation. Restoration actions can range from inexpensive, passive approaches that involve little more than removal of the disturbances so natural recovery can occur, to much more costly and active restoration measures where the stream cannot recover naturally. Urban stream restoration projects can effectively improve portions of badly degraded streams. However, where substantial intervention is needed, these efforts can be costly (as much as $1 million per mile of stream).

Today, many of the opportunities for stream restoration are also found in agricultural areas. Based on our experience during the Survey, farmers in Maryland have expressed a general willingness to modify the way they farm. For example, many are willing to use ***Best Management Practices***, such as no-till farming and contour plowing, to better protect and restore aquatic resources, but not at the expense of their livelihoods. A clear challenge for the future will be to protect and restore farmland streams without jeopardizing our farming heritage.

There are many ways we can all help keep our streams healthy:

- **don't over-fertilize lawns**
- **stop septic system seepage**
- **plant trees, shrubs, and ground cover to reduce runoff**

Replanting riparian buffers is one of many ways we can work together to restore our streams.
Photo courtesy of MD DNR

In addition to impacts from land development, our growing and seemingly insatiable demand for energy is a current and future problem for Maryland streams. As Marylanders continue their exodus from existing urban areas and move into larger homes that are farther from their workplaces, fuel consumption and the number of vehicle miles traveled in Maryland increases annually, and the amount of nitrogen and acids added to streams from the atmosphere continues to be a major problem. New regulations for air and water quality management have helped to reduce some types of impacts, but significant problems remain. For example, almost one-fifth of Maryland's stream miles are affected by acid rain, and with expected increases in population and vehicle miles, the amount of nitrogen that ends up in streams and the Chesapeake Bay is expected to increase each year.

In spite of all the problems with Maryland's streams, their future is bright in many respects. We have many opportunities to protect our healthy streams, improve those that are unhealthy, and change our lifestyles to reduce our "footprint" on our streams. Results of the Survey provide valuable information for tracking these improvements, but we'll need to work together to make it happen.

It Will Take Teamwork

We Marylanders need to work together to protect and restore the health of our streams. If we are to do this effectively, we need to acknowledge the extent of the problem and educate others. Then, we need to make a sustained commitment to change our present behavior and correct the mistakes of the past. Our children, grandchildren, and *their* grandchildren are all depending on us to do the right thing.

Results of the Survey have helped demonstrate that there are no longer any pristine streams in Maryland. A disturbing number of streams are unhealthy, and rarely is there a single cause of the degradation we observed. However, in spite of water quality and habitat problems revealed by the Survey, many healthy streams still exist and protection of these streams should be a top priority.

Stream restoration project in Sawmill Creek; Patapsco River basin (during channel reconstruction in 1994 and after in 1997). This project involved the cooperation of many state and local agencies as well as concerned citizens. Since completion of the project, the once badly eroding stream channel has been stabilized and aquatic life is recovering.
Photos by Larry Lubbers

Stream restoration will not be easy. However, challenges create opportunities. The challenge of protecting and restoring streams for future generations of Marylanders should be considered as a wealth of opportunities.

Two state agencies, Maryland Department of the Environment and Maryland DNR, are already working together to improve the health of Maryland's streams using Survey data. A Biocriteria Advisory Committee, composed of federal and state agencies, environmental organizations, industry, and academia is determining how to use the Survey biological data in water quality regulations. The Committee will develop a process of using the data to assess streams for the next Clean Water Act biennial report to Congress and to prepare Maryland's list of impaired waters.

How can you help? First, visit Maryland DNR's web page (see last page) or your local library and learn more about Maryland streams and their problems. Then take a long, hard look at your daily activities to find ways to lessen your impact on streams and the

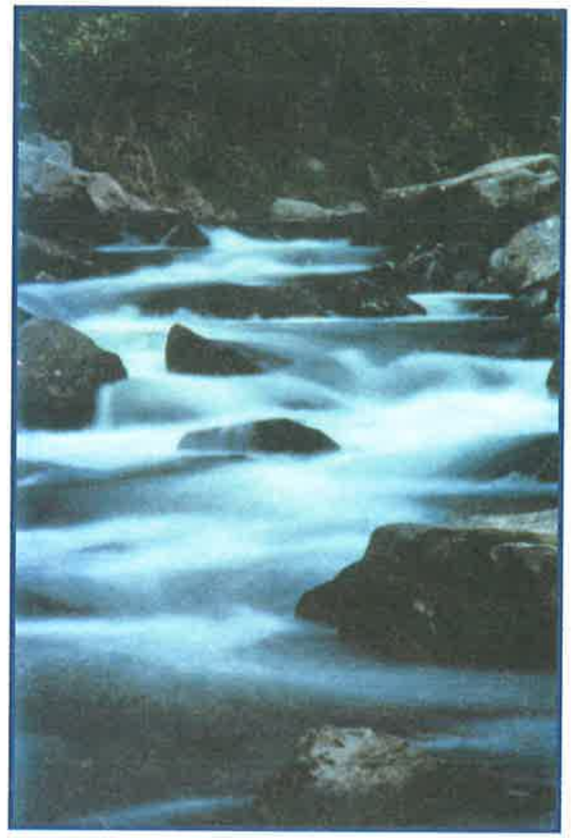
Maryland's Tributary Teams—comprised of local citizens, farmers, business leaders, and government officials appointed by the Governor—are working to keep your local streams and rivers clean and healthy. They understand that the condition of the Chesapeake Bay can be no better than the condition of the waterways that link the upland landscape to the Bay.

Examples of organizations with stream monitoring, protection, or restoration programs in Maryland. See the last page for contact information.

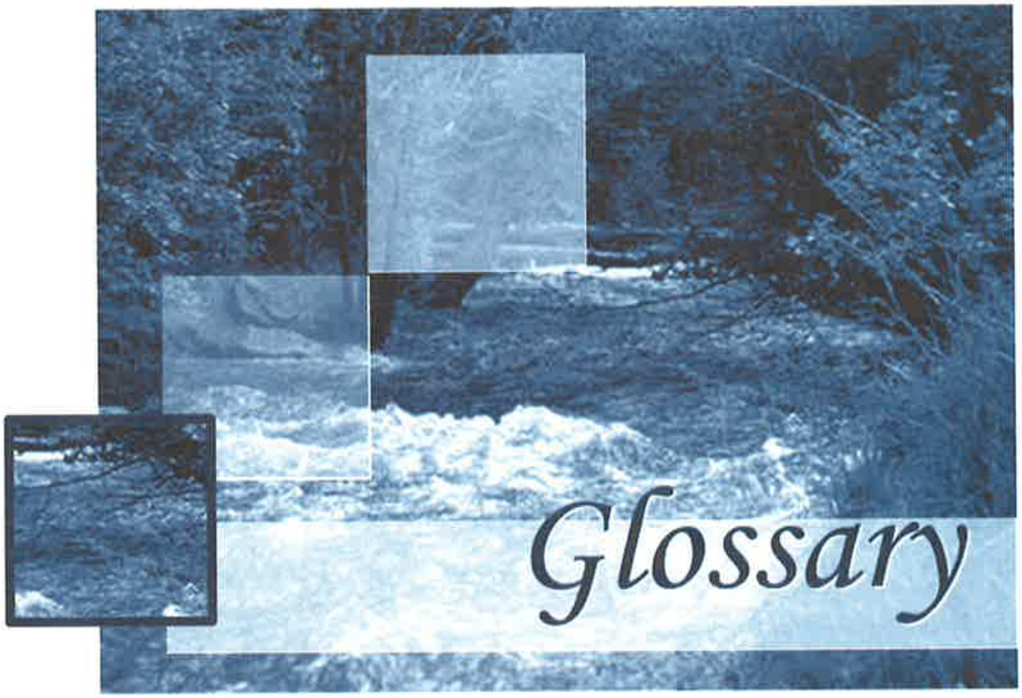
- **Audubon Naturalists Society**
- **Maryland Save Our Streams**
- **Montgomery and Prince Georges County Stream Teams**
- **Tributary Teams**
- **Trout Unlimited**

environment as a whole. Consider joining or starting a citizens group that conducts activities that interest you. For example Maryland's Tributary Teams—partnerships between citizens, local governments, and State and Federal agencies—are working throughout Maryland to reduce nutrient and sediment pollution and restore habitat in the rivers and streams that feed the Bay. The ten Teams, one for each major Chesapeake Bay river basin, promote best management practices for farmers, developers and homeowners; educate their local communities about water quality and habitat protection; and work with State and local agencies to prevent pollution and protect water quality. Grassroots monitoring, on-the-ground restoration activities, and teaching others are but a few of the many potential ways you could get involved.

Finally, consider contacting your elected leaders to tell them that you are concerned about protecting and restoring our watersheds and streams and you want them to represent your concerns and act accordingly. Local governments play a critical role in stream protection and restoration through land use decisions and local stream restoration and monitoring efforts. Together we all can save our priceless streams for many generations to come.



Protecting our healthy streams before they need restoration should be a priority.
Photo courtesy of MD DNR



acid mine drainage (AMD) - Acidic, heavy-metals-laden stream contamination resulting from the drainage of water that contains acidic soils and tailings (residues) from the mining process. Usually associated with surface and underground coal mining.

acid rain - A term in common use that implies the deposition of acid materials in wet precipitation (rain, snow, fog) as well as in the dry precipitation of dust and gases. One source is the combining of rain and sulphur dioxide emissions—a by-product of combustion of fossil fuels.

alkaline - The "opposite" of acid, a solution or substance having a high concentration of (OH) ions that can buffer or neutralize an acid. An example of an alkaline substance is lime used to neutralize soil acidity on farm fields and lawns.

amphipod - A small crustacean having a laterally compressed (i.e. right and left sides are close together) body.

anadromous - Fish that mature in salt water and migrate to freshwater to spawn.

arable land - Land suitable for farming.

benthic macroinvertebrate - Aquatic animals larger than 1/2 millimeter, without backbones, dwelling on or in the bottom of aquatic environments. Examples are clams, crayfish, and several types of aquatic insect larvae.

benthos - Biota closely associated with the bottom of a water body.

Best Management Practice (BMP) - A practice or combination of practices determined to be the most effective means of preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.

baseflow - Sustained, low flow in a stream, primarily from groundwater discharge. Sometimes known as dry weather flow.

biological integrity - The condition of the biological communities (usually benthic macroinvertebrates and/or fish) of a waterbody based on a comparison to a reference that is a relatively undisturbed system and represents the best quality to be expected for the ecoregion.

biota - All of the organisms, including animals, plants, fungi, and microbes, found in a given area.

blackwater - A naturally occurring, dark colored stream, wetland, lake, or river. These naturally acidic water bodies are darkly colored by tannins leaching from leaves and other organic material.

buffer - A solution resistant to pH changes, or whose chemical makeup tends to neutralize acids or bases without a change in pH. Surface waters and soils with chemical buffers are not as sensitive to acid deposition as those with poor buffering capacity.

catadromous - Fish that mature in fresh water and migrate to salt water to spawn.

channelization - The artificial enlargement, straightening, or realignment of a stream channel.

detritus - Disintegrated or broken up mineral or organic material in a water body.

dissolved oxygen - Gaseous form of oxygen in solution with water, abbreviated as DO and measured as mg/L (milligrams per liter) or ppm (parts per million).

duff - The organic layer on top of mineral soil consisting of fallen leaves and other decomposing vegetation. Thick layers of duff are often found on the floors of undisturbed forests.

eutrophication - The process by which streams and other water bodies become enriched with dissolved nutrients, resulting in increased growth of algae and other microscopic plants.

embayment - An indentation in the shoreline forming an open bay.

fall line - A line roughly along Interstate 95 joining areas of relatively steep gradient on several rivers on Maryland's western shore. The line marks the geographical area where each river descends from the hilly Piedmont to the flat and sandy Coastal Plain. It also marks the limit of upstream commercial navigation.

gabion - A wire cage, usually rectangular, filled with rock and used in flood control or for channel and bank stabilization.

habitat - The environment or specific surroundings where plants and animals live and grow.

herpetofauna - A collective term for reptiles and amphibians.

Index of Biotic Intregity (IBI) - A combination of measures, or metrics, that describe community structure, function and pollution sensitivity and are used to assess the health of an aquatic ecosystem.

impervious surface - Hard, non-porous surfaces such as roads, parking lots, and rooftops that prevent precipitation from soaking into the ground, thus increasing surface runoff.

meander - The winding of a stream channel.

migration corridors - Narrow areas of habitat through which animals may travel to reach larger habitat areas.

nitrate - The most biologically available form (NO_3) of the nutrient, nitrogen; technically referred to as nitrate-nitrogen.

non-point source - Pollution that does not originate from a definable point (e.g., soil or urban runoff).

nutrients - Any chemical element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus. When available in excess quantities, these function as pollutants by fueling abnormally high organic growth in waterbodies.

pH - An expression of both acidity and alkalinity on a scale of 0 to 14, with 7 representing neutrality; numbers less than 7 indicate increasing acidity and numbers greater than 7 indicate increasing alkalinity.

phosphorus - An element that serves as a plant nutrient. Phosphorus is most easily used by plants in the form of orthophosphate (PO_4).

point source discharge - Pollutant discharge that originates from an identifiable point such as a pipe.

protists - Single-celled organisms that live freely or in small colonies, such as protozoans and algae. Most protists were formerly classified as either animals or plants.

riffle - A rocky, shallow, turbulent area of a stream or river where oxygen is physically introduced into the water.

riparian buffer - A vegetated protective area next to a water body serving as a barrier against polluted runoff and a habitat corridor for terrestrial animals.

river basin - The land area drained by a river and its tributaries.

sediment - Mud, sand, silt, clay, and other debris from both organic and inorganic sources that is either suspended in or settles to the bottom of a water body.

stormwater - Rainwater that reaches a stream or other water body as surface runoff without soaking into the ground. The water may enter the stream by direct runoff, or enter a system of channels and pipes designed to carry collected rainwater directly to a stream.

stream order - Numbers assigned to streams according to their position within a drainage network. Streams that have no tributaries are first order; streams that receive only first order tributaries are second order; and larger branches that form when two second order tributaries combine are third order, and so on. Stream order designations often vary according to map scale.

substrate - Submerged mineral or vegetative surfaces used by biota for attachment, movement, or shelter. Stream substrates include gravel, cobble, boulder, roots, leaves, and limbs.

taxa - The plural of taxon. The named classification unit to which individuals are assigned. Higher taxa, such as genus, family, and order, are those above the species level.

watershed - The area of land from which rainfall (and/or snow melt) drains into a single point. Watersheds are sometimes referred to as drainage basins or drainage areas. Ridges of higher ground generally form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.

Technical Appendix

This Technical Appendix provides a synopsis of the approach and methods used for the Maryland Biological Stream Survey (the Survey), the sole source of data for this report. Although information on Maryland streams is available from other sources (e.g., other Maryland Department of Natural Resources programs, Maryland Department of the Environment, county agencies, and citizen groups), the Survey's consistent statistical design and methods employed throughout Maryland made it the best program to provide, for the first time, basinwide and statewide estimates of stream condition. Details of the Survey's results may be found in ***State of the Streams: 1995-1997 Maryland Biological Stream Survey Results*** available from DNR (see page 52).

Overview of the Survey

The Maryland Biological Stream Survey is intended to provide statistically unbiased estimates of the condition of first through third-order (wadeable) non-tidal streams and rivers of Maryland on a local (e.g., drainage basin or county) as well as a statewide scale. The survey is based on a probabilistic stream sampling approach where random selections are made from all sections of streams in the state that can physically be sampled. The approach supports statistically valid population estimation of variables of interest (e.g., largemouth bass densities, miles of streams with degraded physical habitat, miles of streams with poor Index of Biotic Integrity scores, etc.). When repeated, the Survey will also provide a basis for assessing future changes in ecological condition of flowing waters of the state. At present, plans are to repeat the Survey at regular intervals and expand the approach to larger streams and tidal creeks.

Sample Design

The study area for the Survey includes each of the major drainage basins of the state (assessments for 17 of these are contained in this report) and a total of three years is required to sample all basins. For logistical reasons, the state was divided into three geographic regions (east, west, and central) with five to seven basins in each region. Each basin was sampled at least once during 1995-1997, and one basin in each region was sampled twice so that data collected in different years could be combined into a statewide estimate for each variable of interest.

The sampling frame for the Survey was constructed by overlaying basin boundaries on a map of all blue line stream reaches in the state as digitized on a U.S. Geological Survey

1:250,000 scale map (see map inside front cover). Sampling within basins is restricted to non-tidal, first, second, and third-order (Strahler stream order system) stream reaches, excluding unwadeable or otherwise unsampleable areas. An additional restriction was that sampling was restricted to public lands or privately-owned sites where land-owner permissions were obtained. Overall success in obtaining landowner permissions was about 90%.

Sample sites were selected from a comprehensive list of stream reaches in all river basins. To provide adequate information about each size of stream, an approximately equal number of first, second, and third-order streams were sampled during spring and summer, with the number of sites of each order in a basin being proportional to the number of stream miles (of an order) in the entire state. Estimates of condition (e.g., fish population; stream health as good, fair, or poor) per mile of stream were made by extrapolating conditions in the 75 m sample segment to the number of stream miles (weighted by order) using 1:250,000 scale maps. Note: According to the 1:250,000 scale maps used for the Survey, the total number of first, second, and third-order stream miles in Maryland is 8,800. This number will vary corresponding to the map scale used.

Sample Collection and Data Analysis

Benthic macroinvertebrates and water quality samples were collected during the spring index period from March through early May, while fish, herpetofauna, *in situ* stream chemistry, and physical habitat sampling were conducted during the low flow period in the summer, from June through September.

In the spring, single grab samples of water were collected and analyzed for pH, acid-neutralizing capacity (ANC), sulfate, nitrate-nitrogen, conductivity, and dissolved organic carbon (DOC) in the laboratory. These variables primarily characterize the sensitivity of the streams to acid deposition, and to other anthropogenic stressors to a lesser extent.

Benthic macroinvertebrates were collected in the spring using dipnets in the most productive habitat(s) (e.g., riffles, rootwads, aquatic vegetation) available in the 75 m segment. About 2 m^2 of stream substrate were sampled at each site and pooled. Preserved samples were subsampled (100 +/- 10%) in the laboratory and identified to genus (if possible).

Habitat assessments were conducted in the summer using metrics largely patterned after EPA's Rapid Bioassessment Protocols and Ohio EPA's Qualitative Habitat Evaluation Index (QHEI) in the designated 75 m stream segments. Riparian habitat measurements were based on the surrounding area within 5 m of the segment. Other qualitative measurements included (1) aesthetic value, based on evidence of human refuse; (2) remoteness, based on the absence of detectable human activity and difficulty in accessing the segment; (3) land use, based on the surrounding area immediately visible from the segment; (4) general stream character, based on the shape, substrate, and vegetation of the segment; and (5) bank erosion, based on the kind and extent of erosion present. Quantitative measurements at each segment included flow, depth, wetted width, velocity, and stream gradient.

Fish and herpetofauna were sampled during the summer index period using quantitative, double-pass electrofishing of the 75 m stream segments. Blocking nets were placed at each end of the segment, and one or more direct-current, backpack electrofishing units were used to sample the entire segment using double-pass depletion. All fish captured during each electrofishing pass were identified, counted, weighed in aggregate, and up to 100 individuals of each species were examined for external anomalies such as lesions and tumors. All gamefish captured were also measured for length. Any amphibians, reptiles, freshwater molluscs, and submerged aquatic vegetation either in or near the stream segment were identified.

Data collected from each sample site were used to develop statewide and basin-specific estimates of totals, means (or averages), proportions, and percentiles for the parameters of interest. The amount of variability (or margin of error) associated with any estimate of a total, mean, proportion, or percentile was determined by calculating a standard error, a statistic that measures the reliability of an estimate. A standard error also provides a statistical basis for deciding if the observed changes in any parameter of interest over time or space are significantly different or simply due to chance alone.

For all phases of the Survey, there was an ongoing, documented program of quality assurance/quality control (QA/QC). The QA/QC program used by the Survey allows for generation of data with known confidence.

Index of Biotic Integrity

The steps in developing Indices of Biotic Integrity (IBIs) were the same for both fish and benthic macroinvertebrates. Criteria for both reference and degraded sites were determined based on water chemistry, physical habitat, and land use. Ecologically-relevant geographic strata were determined using cluster analysis and nonmetric multidimensional scaling. Candidate metrics were evaluated for 1) their ability to discriminate (based on classification efficiency) between reference and degraded sites, and 2) for redundancy. The final suite of metrics used in the IBIs contained those ecologically significant metrics with the best classification efficiency. Both IBIs were validated using an independent data set and overall classification efficiencies were calculated.

The potential range of IBI scores was from 1.0 to 5.0. Narrative ratings for stream quality were assigned as in the table below. In this report, good, fair, and poor ratings of stream quality were indicated by red, yellow, and green, respectively.

IBIs were not calculated for selected sampling sites. For instance, no fish IBIs were calculated for those sites having upstream watersheds less than 300 acres, since small, shallow streams may naturally support few fish species. In these small streams the IBI may indicate natural conditions rather than anthropogenic stresses. Benthic macroinvertebrate IBIs were not calculated for sites with small subsample sizes (i.e., less than 60 organisms where no obvious impairment was present). Seventeen percent of all sites with both fish and benthic macroinvertebrate samples had benthic IBIs but no fish IBIs.

To provide a more integrated picture of overall stream health, fish and benthic macroinvertebrate IBIs were combined (where both IBIs were available) into a Combined Biotic Index (CBI). CBI scores were produced by calculating the mean IBI score for both benthic and fish IBIs if both were available. If both were not available, one or the other IBI was used alone for the CBI. The numbering and coloring scheme described above for the IBIs were used for the CBI.

Watersheds

Although the Survey provides information on a major river basin scale, many readers may want stream information based on other watershed designations. For example, Maryland's Tributary Strategies divide the state into 10 river basins (Figure A1), while for some readers, smaller watershed information may be desired (Figure A2). Table A1 provides a cross reference for major river basins, Tributary Strategies Basins, and watersheds.

Good (IBI score 4.0 - 5.0)	Comparable to reference streams considered to be minimally impacted.
Fair (IBI score 3.0 - 3.9)	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of minimally impacted streams.
Poor (IBI score 1.0 - 2.9)	Significant to strong deviation from reference conditions, with many to most aspects of biological integrity not resembling the qualities of minimally - impacted streams.

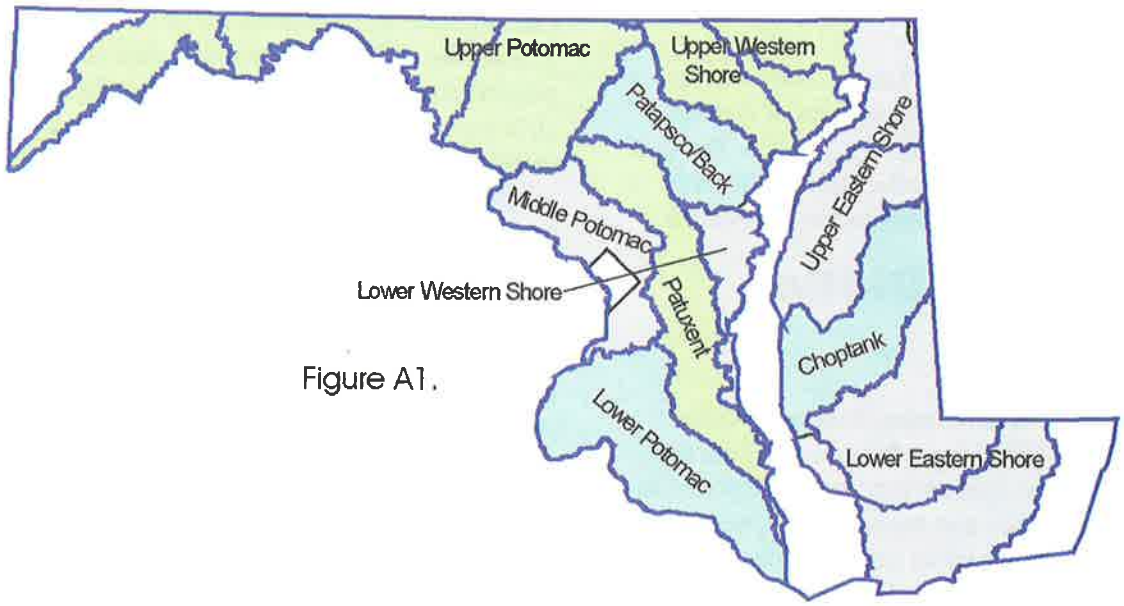


Figure A1.

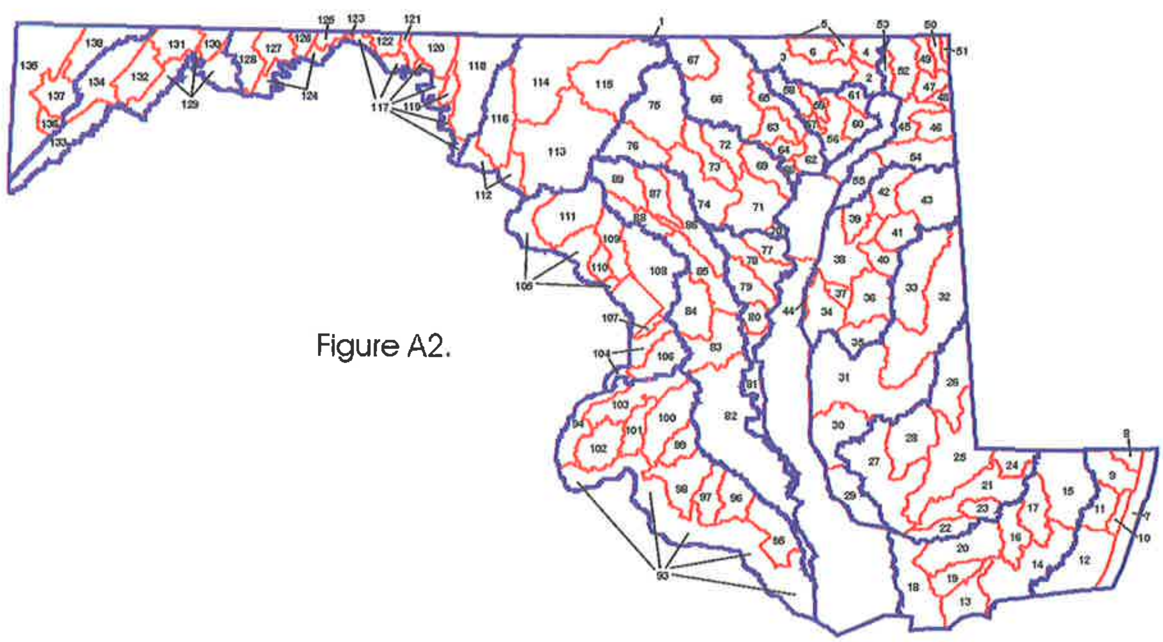


Figure A2.

Figure A1 (above) and A2 (below). Maryland's 10 Tributary Strategies basins are shown in Figure A1. Figure A2 shows the 138 watersheds (in red) that are usually more familiar to most Maryland residents. The blue lines in both maps show the boundaries of the major river basins that are the reporting units in this report. See Table A1 on page 51 for a list of each watershed, its corresponding major river basin, and Tributary Strategies basin.

Table A1. Watersheds, major river basins, and Tributary Strategies basins in Maryland.

Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin	Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin	Watershed No.	Name	Maj.River Basin	Trib. Strat. Basin
1	Conewego Creek	N/A	N/A	46	Bohemia River	EL	UES	94	Potomac River M tidal	LP	LPR
2	L Susquehanna River	SQ	UWS	47	Upper Elk River	EL	UES	95	St. Mary's River	LP	LPR
3	Deer Creek	SQ	UWS	48	Back Creek	EL	UES	96	Breton Bay	LP	LPR
4	Octoraro Creek	SQ	UWS	49	Little Elk Creek	EL	UES	97	St. Clements Bay	LP	LPR
5	Conowingo Dam Susq R	SQ	UWS	50	Big Elk Creek	EL	UES	98	Wicomico River	LP	LPR
6	Broad Creek	SQ	UWS	51	Christina River	EL	UES	99	Gilbert Swamp	LP	LPR
7	Atlantic Ocean	OC	N/A	52	Northeast River	EL	UES	100	Zekiah Swamp	LP	LPR
8	Assawoman Bay	OC	N/A	53	Furnace Bay	EL	UES	101	Port Tobacco River	LP	LPR
9	Isle of Wight Bay	OC	N/A	54	Sassafras River	EL	UES	102	Nanjemoy Creek	LP	LPR
10	Sinepuxent Bay	OC	N/A	55	Stillpond-Fairlee	EL	UES	103	Mattawoman Creek	LP	LPR
11	Newport Bay	OC	N/A	56	Bush River	BU	UWS	104	Potomac River U tidal	PW	MPR
12	Chincoteague Bay	OC	N/A	57	Lower Winters Run	BU	UWS	105	Potomac River MO Cnty	PW	MPR
13	Pocomoke Sound	PC	LES	58	Atkisson Reservoir	BU	UWS	106	Piscataway Creek	PW	MPR
14	Lower Pocomoke River	PC	LES	59	Bynum Run	BU	UWS	107	Oxon Creek	PW	MPR
15	Upper Pocomoke River	PC	LES	60	Aberdeen Proving Ground	BU	UWS	108	Anacostia River	PW	MPR
16	Dividing Creek	PC	LES	61	Swan Creek	BU	UWS	109	Rock Creek	PW	MPR
17	Nassawango Creek	PC	LES	62	Gunpowder River	GU	UWS	110	Cabin John Creek	PW	MPR
18	Tangier Sound	PC	LES	63	Lower Gunpowder Falls	GU	UWS	111	Seneca Creek	PW	MPR
19	Big Annemessex River	PC	LES	64	Bird River	GU	UWS	112	Potomac River FR Cnty	MP	LPR
20	Manokin River	PC	LES	65	Little Gunpowder Falls	GU	UWS	113	Lower Monocacy River	MP	LPR
21	Lower Wicomico River	NW	LES	66	Loch Raven Reservoir	GU	UWS	114	Upper Monocacy River	MP	LPR
22	Monie Bay	NW	LES	67	Prettyboy Reservoir	GU	UWS	115	Double Pipe Creek	MP	LPR
23	Wicomico Creek	NW	LES	68	Middle River - Browns	GU	UWS	116	Catoctin Creek	MP	LPR
24	Wicomico River Head	NW	LES	69	Back River	PP	PBR	117	Potomac River WA Cnty	UP	UPR
25	Nanticoke River	NW	LES	70	Bodkin Creek	PP	PBR	118	Antietam Creek	UP	UPR
26	Marshyhope Creek	NW	LES	71	Baltimore Harbor	PP	PBR	119	Marsh Run	UP	UPR
27	Fishing Bay	NW	LES	72	Jones Falls	PP	PBR	120	Conococheague Creek	UP	UPR
28	Transquaking River	NW	LES	73	Gwynns Falls	PP	PBR	121	Little Conococheague	UP	UPR
29	Honga River	CK	CPK	74	Patapsco River L N Br	PP	PBR	122	Licking Creek	UP	UPR
30	Little Choptank	CK	CPK	75	Liberty Reservoir	PP	PBR	123	Tonoloway Creek	UP	UPR
31	Lower Choptank	CK	CPK	76	S Branch Patapsco	PP	PBR	124	Potomac River AL Cnty	UP	UPR
32	Upper Choptank	CK	CPK	77	Magothy River	WC	LWS	125	Little Tonoloway Creek	UP	UPR
33	Tuckahoe Creek	CK	CPK	78	Severn River	WC	LWS	126	Sideling Hill Creek	UP	UPR
34	Eastern Bay	CR	UES	79	South River	WC	LWS	127	Fifteen Mile Creek	UP	UPR
35	Miles River	CR	UES	80	West River	WC	LWS	128	Town Creek	UP	UPR
36	Wye River	CR	UES	81	West Chesapeake Bay	WC	LWS	129	Potomac River L N Branch	NO	UPR
37	Kent Narrows	CR	UES	82	Patuxent River lower	PX	PTX	130	Evitts Creek	NO	UPR
38	Lower Chester River	CR	UES	83	Patuxent River middle	PX	PTX	131	Wills Creek	NO	UPR
39	Langford Creek	CR	UES	84	Western Branch	PX	PTX	132	Georges Creek	NO	UPR
40	Corsica River	CR	UES	85	Patuxent River upper	PX	PTX	133	Potomac River U N Branch	NO	UPR
41	Southeast Creek	CR	UES	86	Little Patuxent River	PX	PTX	134	Savage River	NO	UPR
42	Middle Chester River	CR	UES	87	Middle Patuxent River	PX	PTX	135	Youghiogheny River	YG	N/A
43	Upper Chester River	CR	UES	88	Rocky Gorge Dam	PX	PTX	136	Little Youghiogheny R	YG	N/A
44	Kent Island Bay	CR	UES	89	Brighton Dam	PX	PTX	137	Deep Creek Lake	YG	N/A
45	Lower Elk River	EL	UES	93	Potomac River L tidal	LP	LPR	138	Casselman River	YG	N/A

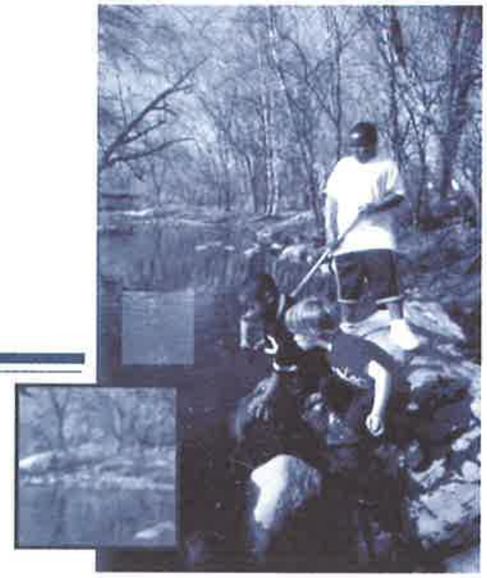
Abbreviations for major river basins.

BU - Bush	OC - Ocean Coastal
CK - Choptank	PC - Pocomoke
CR - Chester	PP - Patapsco
EL - Elk	PW - Potomac Washington Metro
GU - Gunpowder	PX - Patuxent
LP - Lower Potomac	SQ - Susquehanna
MP - Middle Potomac	UP - Upper Potomac
NO - North Branch Potomac	WC - West Chesapeake
NW - Nanticoke/Wicomico	YG - Youghiogheny

Abbreviations for Tributary Strategies basins.

CPK - Choptank	PBR - Patapsco-Back River
LES - Lower Eastern Shore	PTX - Patuxent
LPR - Lower Potomac River	UES - Upper Eastern Shore
LWS - Lower Western Shore	UPR - Upper Potomac River
MPR - Middle Potomac River	UWS - Upper Western Shore

For more information on the Quality of Maryland's Streams...



Maryland Biological Stream Survey

For current information on the Survey, visit Maryland DNR's World Wide Web homepage at http://www.dnr.state.md.us and wade on over to ***Bays and Streams.*** A detailed summary of three years of Survey sampling is contained in the report, ***State of the Streams: 1995-1997 Maryland Biological Stream Survey Results.*** Call Ann Smith at 1-(877)-620-8DNR (extension 8611) or (410) 260-8611 (email: asmith@dnr.state.md.us) for a copy of this or other Survey reports (expect a charge to cover printing and postage) or to add your name to the mailing list for our newsletter, ***An Eye on Maryland Streams.*** The newsletter may also be found online at DNR's website noted above.

If you would like more information about the methods used to sample Maryland streams and analyze data, call Ann Smith at the above number and ask for the ***MBSS Sampling Manual*** (expect a charge to cover printing and postage).

Maryland Watershed and Citizen Monitoring Organizations

For information on Maryland's ***Tributary Strategies***, call 1-(877)-620-8DNR (extension 8710) or (410) 260-8710 or check out http://dnr.state.md.us/Bay/tribstrat. To contact other watershed organizations in Maryland, go to the Alliance for the Chesapeake Bay's website at http://www.acb-online.org. Also, the Maryland Water Monitoring Council works to foster cooperation among groups involved in all types of water monitoring activities in Maryland. Learn more about the Council at http://www.mgs.md.gov/mwmc/. For information on Maryland's volunteer monitoring programs, call the state Volunteer Monitoring Coordinator at (410) 260-8696 or email her at rbruckler@dnr.state.md.us or visit the DNR website.

Parris N. Glendening, Governor
Kathleen Kennedy Townsend, Lt. Governor

Sarah J. Taylor-Rogers, Ph. D., Secretary
Stanley K. Arthur, Deputy Secretary

OMB Control Number: 2090-0019

WE NEED YOUR HELP...

We would like to know if *From the Mountains to the Sea: the State of Maryland's Freshwater Streams* provides you with useful information and if you would like to receive future reports. The estimated time it takes to complete this survey is less than three minutes. Your response to the following questions will help us meet your needs:

1. What best describes the function of your organization/responsibility?

① General Public	② Government	③ Legislation	④ Environmental	⑤ Academia	⑥ Planner	⑦ Other

2. Is this report easy to understand?

① Yes	② No

3. The contents of the report were useful to me.

① Strongly Disagree	② Disagree	③ Neutral	④ Agree	⑤ Strongly Agree

4. Which part(s) of the report did you find the most useful or least useful?

	The most useful	The least useful
a. Introduction	①	②
b. The State of Maryland's Streams	①	②
c. The Future of Maryland's Streams	①	②
d. It Will Take Teamwork	①	②

5. If information was provided using the Geographic Information Systems (GIS) data, would it be useful to you?

① Yes	② No	③ Don't Know

6. Would you like to receive a copy of future reports? ① Yes ② No

If yes, please provide a mailing address:

Name ______________________________

Organization ______________________________

Address ______________________________

Town/City ______________________ State ______________________

Zip Code ______________________ Country ______________________

Other contacts to add to our mailing list: ______________________________

Thank you for taking the time to respond to this survey! Please fold the form in half with EPA's return address on the outside, staple/tape shut, and mail. This survey is being administered by the United States Environmental Protection Agency, Region III (Mid-Atlantic Office).

Public reporting burden for this collection of information is estimated to average three (3) minutes per response, including the time for reviewing instructions, gathering information, and completing and reviewing the collection of information. Send comments on the agency's need for this information, the accuracy of the provided burden estimates, and any suggestions for reducing the burden, including the use of automated collection techniques to the Director, OEI, Collection Strategy Division, United States Environmental Protection Agency (Mail Code 2822), Ariel Rios Building, 1200 Pennsylvania Avenue NW, Washington, DC, 20460; and to the Office of Information and Regulatory Affairs, Office of Management and Budget, 725 17th Street NW, Washington, DC, 20503, Attention: Desk Officer for EPA. Include the EPA ICR number and the OMB control number in any correspondence.

---------------------------------(Fold)--------------------------------------

Mid-Atlantic Integrated Assessment
U.S. Environmental Protection Agency
Environmental Science Center
701 Mapes Road
Fort Meade, MD 20755-5350

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

BUSINESS REPLY MAIL

FIRST-CLASS MAIL PERMIT NO. 11663 WASHINGTON DC
POSTAGE WILL BE PAID BY ENVIRONMENTAL PROTECTION AGENCY

U S ENVIRONMENTAL PROTECTION AGENCY
701 MAPES RD STE 5350
FORT MEADE MD 20755-9972