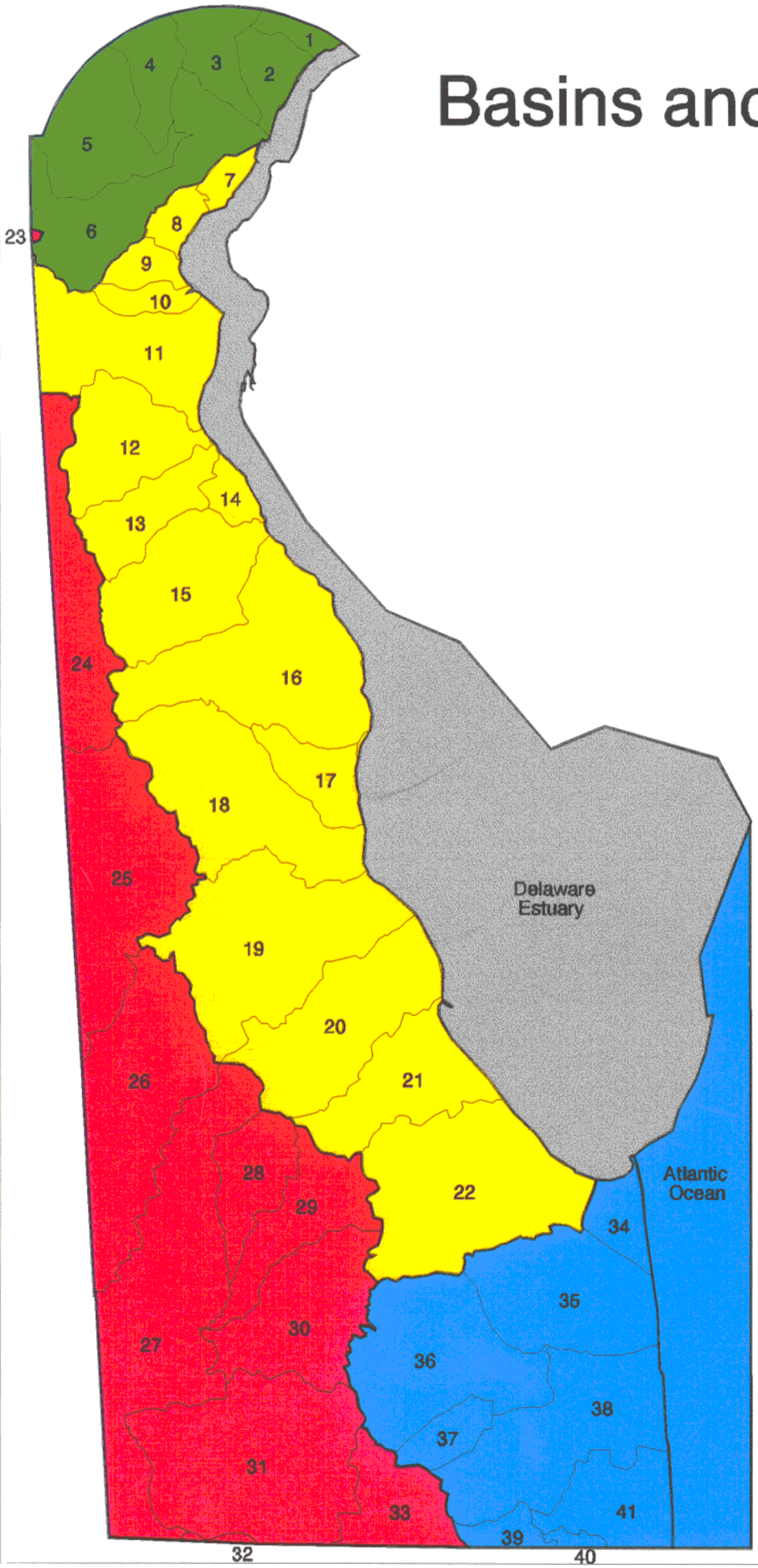
DELAWARE'S
BASINS and WATERSHEDS
ASSESSMENTS

PIEDMONT BASIN

1. Naamans Creek
2. Shellpot Creek
3. Brandywine Creek
4. Red Clay Creek
5. White Clay Creek
6. Christina River

Basins and Watersheds



NORTHERN PIEDMONT
1. Naamans Creek
2. Shellpot Creek
3. Brandywine Creek
4. Red Clay Creek
5. White Clay Creek
6. Christina River

DELAWARE BAY DRAINAGE
7. Delaware River
8. Army Creek
9. Red Lion Creek
10. Dragon Run Creek
11. Chesapeake Delaware Canal
12. Appoquinimink River
13. Blackbird Creek
14. Delaware Bay
15. Smyrna River
16. Leipsic River
17. Little Creek
18. St. Jones River
19. Murderkill River
20. Mispillion River
21. Cedar Creek
22. Broadkill River

CHESAPEAKE BAY DRAINAGE
23. Elk Creek
24. Chesapeake Drainage System
25. Choptank River
26. Marshyhope Creek
27. Nanticoke River
28. Gum Branch
29. Gravely Branch
30. Deep Creek
31. Broad Creek
32. Wicomico River
33. Pocomoke River

INLAND BAYS/ATLANTIC OCEAN
34. Lewes Rehoboth Canal
35. Rehoboth Bay
36. Indian River
37. Iron Branch
38. Indian River Bay
39. Buntings Branch
40. Assawoman
41. Little Assawoman

DELAWARE ESTUARY

PIEDMONT PRELIMINARY ASSESSMENT

Understanding and respecting the relationships that exist in nature among the air, land, water, and living resources as they constantly interact in a dynamic, ever-changing system has prompted DNREC (Department of Natural Resources) to focus on looking at the environment from multiple perspectives in an integrated fashion. This innovative approach--referred to as "Whole Basin Management"--involves monitoring, assessing, and managing Delaware's biological and physical environments as geographic areas, defined on the basis of drainage patterns. Whole basin management approach thus focuses on place-based ecosystem management, whereby a multitude of efforts are directed toward particular areas within each drainage basin. This new approach enables the Department to comprehensively assess the condition of the environment with due consideration to all facets of the ecosystem.

Five major drainage basins encompass Delaware: the Piedmont, Chesapeake Bay, Delaware Bay, Delaware Estuary, and the Inland Bays/Atlantic Ocean. Each basin consists of smaller management units, or sub-basins, which represent the area drained by a river, stream, or creek. Delaware has 41 sub-basins, or watersheds.

For each major basin, a team of scientists, planners, engineers, and managers representing the six different environmental units within the Department is being assembled to carry out a five year, eight-phased plan. The phases begin with planning and range through preliminary assessment, monitoring, analysis of problems and issues, development of management and resource protection strategies, and, finally, implementation of the plan.

The first basin that DNREC assessed under *Whole Basin Management* was the Piedmont Basin in northern New Castle County. A Preliminary Assessment report has been completed for the six watersheds that make up the Piedmont Basin which are: Naamans Creek, Shellpot Creek, Brandywine Creek, Red Clay Creek, White Clay Creek, and the Christina River. The following topics were examined in the Preliminary Assessment: Hydrology, Land Use, Contaminant Sources, Air Quality, Water Quality, and Recreation and Living Resources.

Watershed Hydrology:

Hydrology is the study of water as it interacts with the land, the sea, and the sky. Water is constantly recycled on the Earth as rain, snow, oceans, lakes, streams, hail, and glaciers. Scientists refer to this as the *water cycle.* Human activities can have significant impacts on the water cycle. For example, when vegetation is removed and impervious surfaces such as parking lots, buildings, and highways are added to the landscape, less precipitation can infiltrate the soil causing runoffs. Runoffs can result in flooding and/or cause stream banks to erode. Also, runoffs are the leading cause of nonpoint source pollution. As water runs over land during heavy storms, it can pick up fertilizers, pet waste, and other chemicals and materials and carry these pollutants into our streams, rivers, and lakes. Stormwater management practices can offset some of the adverse impacts caused by urbanization. However, they cannot be viewed as a cure-all. While the technology is improving, stormwater

management practices can provide only partial control.

In fall 1993, the Department conducted biological and habitat assessments in 39 nontidal streams in the Piedmont Basin. Three-fourths of the nontidal streams in the basin were found to have degraded biological conditions; an equal number of sites were deemed moderately and severely degraded. Almost all (90%) of the nontidal streams had undergone some degree of habitat degradation as exhibited by eroded banks, newly deposited sediment in the channel, and lack of shade canopy. Many of these conditions are indicative of urban streams, where roads, parking lots, and other impervious surfaces have increased the frequency and magnitude of peak flows during storms.

Land Use & Comprehensive Planning:

New Castle is at a crossroads in maintaining a balance between development and environmental preservation. Agricultural lands and other open spaces are fast declining. New Castle County is expected to lose a total of 20,000 acres in agricultural land by 2020 to sustain the expected 21% population increase.

In response to the growing concern about the viability of comprehensive planning to direct and manage new development and make land-use decisions, the Delaware general Assembly enacted Senate Bill 116 in June 1995. Through this act, known as "Shaping Delaware's Future," the state began to exert a direct role in the land-use planning process. "Shaping Delaware's Future" established goals to improve the effectiveness of land-use decisions made by state and local governments. The following are some land-use goals that have been identified for the Piedmont Basin:

--Connect land use with environmental quality, and support ecologically oriented planning.
--Link transportation to land use, and improve mobility.
--Support revitalization of brownfields.
--Protect vital farmlands, open spaces, and natural resources.
--Enhance land-use planning and decision making through the use of the Geographic Information System (GIS), with its layers of maps and data.

Contaminant Sources:

A contaminant source is a site that has released, or has the potential to release, hazardous substances to air, soil, ground water, surface water, or sediment. The Piedmont Basin contains a variety of known and potential contaminant sources such as gas stations, factories, landfills, septic systems, and abandoned industrial sites. Other contaminant sources include approximately 650 businesses that produce hazardous waste; 1752 underground storage tanks are in use at 707 facilities (mostly gasoline stations) of which 138 have leaked, impacting ground water; and septic systems and cesspools. The White Clay, Red Clay, and Brandywine watersheds have the most septic systems in the basin. The most common ground water contaminants released from septic systems and cesspools are nitrates. Septic systems and cesspools are slowly being eliminated as the county extends sewer lines into these areas.

Air Quality:

Air quality plays a major part in the Department's Whole Basin Planning Process, and it is a very important factor in the Piedmont Basin's ecology. Although much of Delaware's air pollution is carried into the state on the prevailing winds, a significant amount of pollutants is added right here in the Piedmont Basin. Of all the air pollutants that are monitored and have clean air standards, only ozone occurs at levels that are above the federal standard and are classified as "unhealthy." Pollution control and prevention programs have resulted in the decline of the number of days with "unhealthy" ozone concentrations over the last ten years. These controls, as well as some additional measures, will continue to be needed as population increases in the Piedmont Basin.

Pollution deposition is another problem affecting the Piedmont. This occurs when chemicals in the air are washed out by rain or settle out as dry particles. Acid rain and nitrogen compounds are the chief pollutants deposited in this manner in the Piedmont Basin. These pollutants can affect rainwater's acidity thus can harm aquatic life in lakes and streams.

Many other chemicals known or suspected to be capable of causing harm to people can be detected in air in very low concentrations. These chemicals are often referred to as *air toxics* and can come from many sources including industrial facilities, transportation sources, and chemical processes. The emissions from these sources are quantified on an annual basis and published in the Toxics Release Inventory (TRI). The Piedmont Basin contains over 20 sources included in the TRI. However, TRI data show a significant decrease from 1989 to 1994, in the amount of toxic chemicals released annually.

Water Quality & Quantity:

The Piedmont Basin's many streams and tidal river support approximately 70% of the drinking water for New Castle County. As recently as 1975, Delaware routinely experienced serious water pollution and public health problems as a result of untreated sewage. Since then, localized improvements in water quality have been achieved, as a result of regulatory actions and significant private and public investments in wastewater treatment facilities.

A preliminary assessment of water quality data, completed in 1996 for the Piedmont Basin, indicates a decline in water quality. The study characterized water quality and identified existing and potential problems in streams. In some cases, water quality criteria were frequently violated, or trends indicated potential future problems, or both. Also in 1996, a public health advisory on the consumption of fish taken from several streams in the Piedmont Basin was issued due to elevated levels of polychlorinated biphenyls (PCBs) in the fish.

There are three major sources of water supply: streams, ground water, and transfers from Pennsylvania. Water supply are usually plentiful, but Delaware can have shortage problems during

droughts. Shallow wells also are susceptible to declining water tables during droughts. Since Delawareans rely on ground water for drinking purposes, the protection of ground water resources is critical. Thus, Delaware has a long established water supply management program that involves allocation, conservation, and planning.

Surface Water Quality Trends:

This preliminary study characterized the water for the Piedmont Basin and identifies existing and potential water quality problems in streams through trend and status analysis. It applied all three types of statistical analysis methods, graphical method, estimation method, and test of hypotheses, on each parameter for each sampling location.

The assessment revealed many existing and potential water quality problems. In some cases, water quality criteria were frequently violated or trends indicated potential future problems, or both.

- Enterococcus bacteria -- concentrations frequently exceeded criteria throughout the Piedmont Basin.
- Zinc -- exceedances of criteria occurred frequently along the Red Clay Creek.
- Iron -- violations of criteria occurred along the lower reach of the Christina River.
- Total phosphorus -- excessive concentrations (average above 0.1 mg/l) support the concern for nutrient over enrichment in the Christina River, Brandywine Creek, Red Clay Creek, and White Clay Creek watersheds, however concentrations are on the decline.
- Dissolved oxygen -- its concentrations decreased steadily within the last 26 years in the entire Piedmont Basin, though criteria were not violated frequently. Therefore, trends indicate that future violations will occur frequently.
- Nitrate-nitrogen -- increasing trends in the Christina River, Brandywine Creek, Red Clay Creek , and White Clay Creek during 1970 - 1990 suggest that water quality had declined and will continue to decline in these regions.

Recreation & Living Resources:

In the Piedmont, more than 9,000 acres of land are dedicated to public recreational use in the state, county, and municipal parks. Although the current acreage meets the minimum national standard for recreational space per person, the demand for recreational facilities already has exceeded the capacity of a significant portion of the basin's recreation resources.

Sporting activities such as hunting, fishing, and boating, although limited by suburban sprawl and high human population, provide some of the most unique opportunities in the state. For example freshwater trout fishing is available at six designated trout streams in the basin. Over 30,000 legal-sized trouts are stocked annually along 19 miles of the Piedmont streams.

The Piedmont Basin once supported a rich diversity of plants and animals. Today, nearly 75% of the basin's forest is gone. Delaware has lost a higher percentage of its native plant species than any other state in the United States. The Department of Natural Resources conducts ongoing inventories of

natural communities, as well as rare and declining species, including plants, birds, insects, mussels, reptiles, and amphibians. These data indicate that an alarming number of species once common in the Piedmont Basin are now found in only one or two locations or have become extinct.

The Piedmont Preliminary Assessment Report is the Department of Natural Resources and Environmental Control's effort to present a comprehensive assessment of northern Delaware's environment. It provides a synopsis of environmental information and key issues of concern for northern New Castle County. This information will aid the Department and other local, state, and federal agencies in identifying the environmental issues requiring the greatest attention in this region.

For more information about the Department's Preliminary Assessment Report for the Piedmont Basin, please contact Jenny McDermott, Piedmont Team Leader, at (302)739-3451.

Refer to pamphlet entitled Whole Basin Management, Piedmont Environmental Profile-- An Environmental Assessment of Northern Delaware, DNREC, Doc. No. 40-01/97/07/02.

Biological Quality of Nontidal Streams in the Piedmont

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Division of Water Resources
October 10, 1996

Introduction

Nontidal streams are by far the most widespread and extensive aquatic resources in the Piedmont region with 272 miles of ephemeral and perennial streams. Approximately 60% of the resource has flow year-round (perennial) while 40% is made up of small headwater channels that go dry for part of the year (ephemeral). The nontidal stream resource extends from the headwaters of the major watersheds in Pennsylvania and Maryland down to the head of tide at (1) Smalley's Pond near Christiana, (2) just below the confluence of the White Clay, Red Clay, and Mill Creeks near Stanton, (3) the Brandywine River at the Route 13 bridge in downtown Wilmington, and (4) Naamans and Shellpot Creeks at the Delaware River.

The ecological quality of surface waters, including nontidal streams, is made up of a complex web of attributes that interact together to support the system as a whole. Each attribute can be assessed using a variety of discrete measurements. Assessments have traditionally focused on chemical and flow measurements because these best describe point sources of pollution that fall under regulatory control. Measures of biological quality using resident organisms reflect a wide range of attributes of the system and thus can detect impacts from both point and nonpoint sources. Resident organisms provide a direct measure of aquatic life use attainment required by the Clean Water Act.

A wide variety of aquatic organisms are found in nontidal streams including algae and aquatic mosses, aquatic and semi-aquatic vascular plants (e.g., wild celery Vallisneria spp. and duckweed Lemna spp.), invertebrate animals (e.g., insect larvae and snails) and vertebrate animals (e.g., fish and amphibians). Various studies have been completed over the years that assess the condition of resident aquatic organisms found in nontidal streams in the Piedmont region.

Nontidal streams in the region support a variety of human uses including fishing, swimming, boating, and public water supply. Aquatic organisms are an effective measure of the quality of water supporting these uses. Fishing is a popular activity in all of the major creeks and streams in the region. Canoeing and tubing are popular activities in White Clay Creek and the Brandywine River. Approximately 69% of the potable water in New Castle County comes from surface waters taken directly from nontidal streams or from reservoirs fed by nontidal streams (DNREC 1996). Therefore, the quality of aquatic organisms in the region effects both recreation and human health interests.

In the Fall of 1993, the DNREC collected macroinvertebrate samples and conducted habitat assessment in 39 nontidal streams (Figure 2) within the Piedmont region (DNREC 1994). Sites were randomly selected to provide unbiased estimates of the proportion (percent) of stream miles in the region with three classes of quality: "good" (comparable to reference), "fair" (moderately degraded), and "poor" (severely degraded). This framework provided the basis for an overall assessment of the biological condition of nontidal streams to complement the more detailed assessments that have been completed on specific stream or stream reaches.

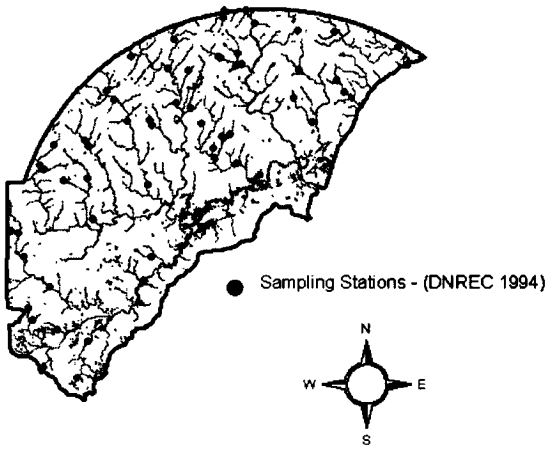
The biological monitoring program within the Division of Water Resources uses aquatic macroinvertebrates as the indicator of biological quality in nontidal streams. Aquatic macroinvertebrates, principally the larval stages of insects, are good indicators of stream quality because they (1) have a short range and thus represent local conditions, are long lived (many have life spans of 1-5 years) and thus reflect long-term conditions, (3) are known to be sensitive to pollution, and (4) are the primary food source for recreationally and economically important fish. These aquatic organisms in turn support terrestrial organisms such as birds and humans. As part of the biological assessment, physical habitat measures are also taken to further broaden the ecological assessment and to assist in the interpretation of the biological data.

Percent area estimates were reported using two biological indices and one habitat index. "Percent of reference" estimates were first determined for each site by comparing quantitative measures (i.e., metrics) from each site to those from least impacted reference sites (i.e., forested watersheds). Each site was then classified into one of the three quality classes using the following criteria:

Class	Biological Quality	Habitat Quality
good	> 67 %	> 88 %
fair	34 to 67 %	60 to 88 %
poor	< 34 %	< 60 %

The percent area (% stream miles) was determined as the percent of the 39 sites in each class. Technical procedures follow those developed by the U.S. Environmental Protection Agency (Plafkin, et al. 1989). Confidence intervals were determined using procedures contained in Walpole and Myers (1976).

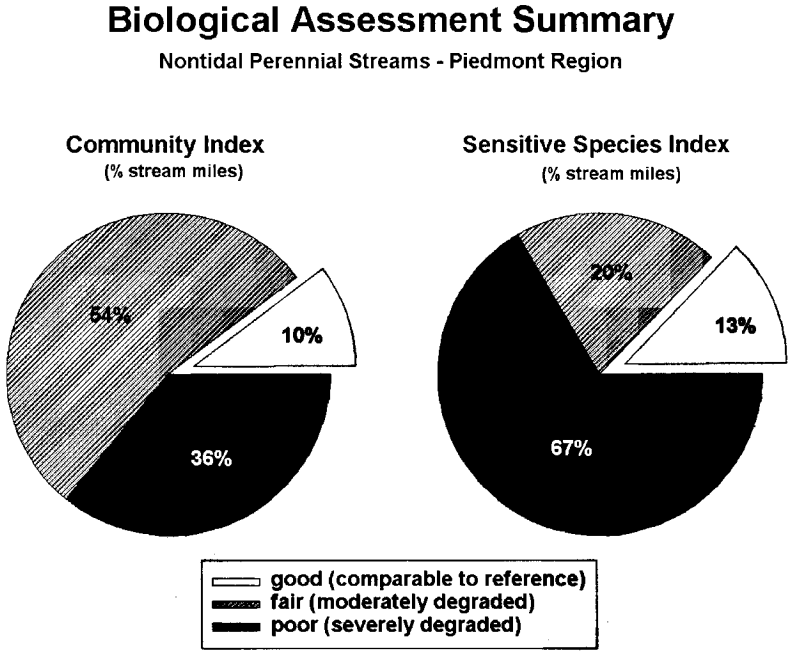
Figure 2 - Stations locations for 1993 study of physical habitat and macroinvertebrate communities for nontidal stream of the Piedmont region.



The two indices used to summarize the biological data included the Community Index (CI) and the Sensitive Species Index (SSI). The CI was used to characterize overall condition and was derived from several measures of the macroinvertebrate community. A "poor" CI classification indicated severe degradation including reduction of taxonomic diversity, loss of sensitive species, and loss of community structure and balance. A "fair" CI classification indicated an intermediate degree of impairment. The SSI was derived using only those organisms that are known to be sensitive to pollution. A "poor" classification using the SSI indicated almost complete loss of sensitive species while a "fair" classification indicated partial loss of sensitive species.

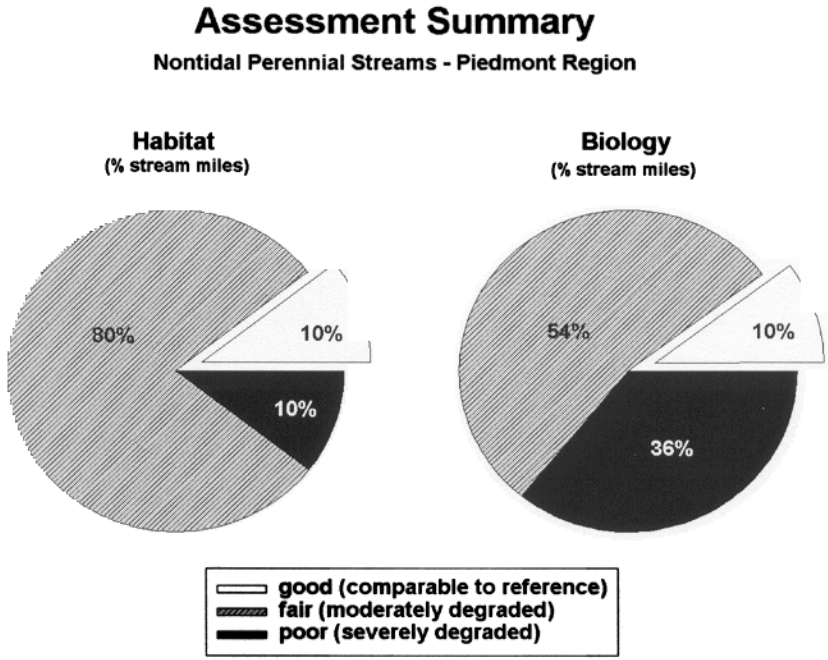
Three-fourths (74%) of nontidal stream resources in the region were found to have degraded biological conditions; an equal number of sites were moderately and severely degraded (Figure 3). Degraded sites were dominated by fly larvae, snails, and worms while "good" sites were dominated by mayfly, stonefly, and caddisfly larvae. Degraded sites were dominated by pollution tolerant species while "good" sites were dominated by pollution sensitive species . Almost all (87%) of the sites in the region showed some loss of sensitive species with two-thirds (67%) having almost complete loss of sensitive species (i.e., "poor") (Figure 3).

Figure 3 - Proportion (%) of nontidal streams in the Piedmont Region with three classes of biological quality using two indices (90% confidence interval of +/- 9-13%).



Almost all (90%) of the nontidal streams had some degree of habitat degradation (Figure 4). Habitat degradation was exhibited by eroded banks, newly deposited sediment in the channel, lack of a shade canopy, and human activity in the riparian zone. Two factors contributed to the degraded habitat conditions of streams in the region. First, stream channels appeared to be unstable , with active erosion along bends and runs, and had newly deposited sediment in the channel. This condition is indicative of urban streams where the impervious surfaces in the watershed (e.g., roads, parking lots, rooftops, etc.) have increased the frequency and magnitude of peak flows. Second, native vegetation (e.g., trees) was often replaced by grass (i.e., lawns) in the riparian zone . Natural wooded riparian zones promote channel stability, moderate stream temperatures, and provide a buffer between streams and contaminant sources .

Figure 4 - Proportion (%) of nontidal streams in the Piedmont Region with three classes of habitat and biological quality (90% confidence interval of +/- 8-13%).

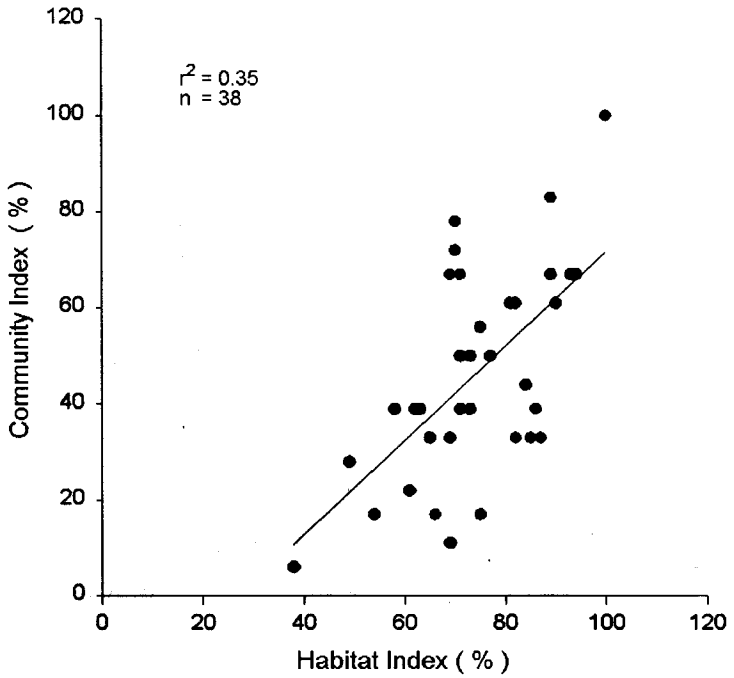


Identification of Problems and Sources

Nonpoint Sources - Urbanization

The 39 sites sampled by DNREC in 1993 were used to provide an initial analysis of the relationships between biological quality, physical habitat quality, and land use. Physical habitat appeared to be an important stressor effecting nontidal streams in the region. The association between biological quality and physical habitat quality ($r = 0.35$, $n = 38$) provided objective evidence that the impacts to physical habitat may be contributing to the biological condition of these streams (Figure 5). This association was further supported by the classification information. The majority of sites classified as "good" or "poor" for one measure received the same classification using the other measure. None of the sites with "good" biology had "poor" habitat.

Figure 5 - Effect of physical habitat on the biological quality on nontidal streams in the Piedmont Region.



Urbanization is a major land use in the region. The habitat conditions at impacted sites were consistent with those associated with urbanization. These included human alteration of the riparian zone, erosion of banks, and deposition of new sediment in channels. Sediment is eroded from stream banks during rainfall events and deposited in the channel where it smothers productive habitats such as pools and riffles. Productive riffles are partially buried in fine sediment in urban streams. Woody material, also important habitat for aquatic organisms, is picked up by storm flows and transported downstream often accumulating in large piles at bridges.

The scatter in the association between biological and physical habitat quality (Figure 5) may be due to the variability in the two measurements or due to stressors other than physical habitat. Other stressors likely in the region include temperature, (due to lack of shade) chloride (due to road salts), dissolved oxygen (due to nutrient enrichment and lack of shade), and a variety of metal and organic contaminants (due to stormwater runoff). There are insufficient data to determine the relative contributions of these possible stressors.

To further evaluate the relationship between biological condition and urbanization, land use data were compiled for the watersheds above each of the 39 sampling stations. Percent impervious cover estimates for each site were calculated to provide the basis for evaluating

relationships between biological condition and urban land use. The relationships between percent impervious cover and the CI (Figure 6) indicated that the degree of urbanization was associated with the macroinvertebrate community. The association between impervious cover and the CI was particularly strong ($r = 0.71$, $n = 19$) for low density urbanization (< 30% impervious cover).

Figure 6 - The effect of impervious cover on the macroinvertebrate community using the Community Index; see text.

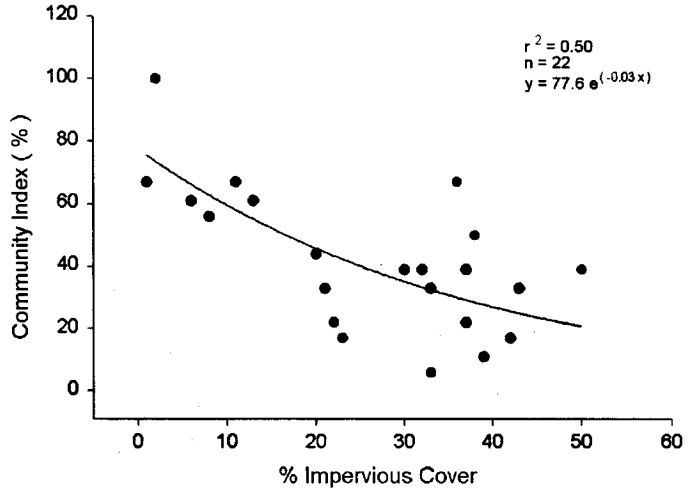
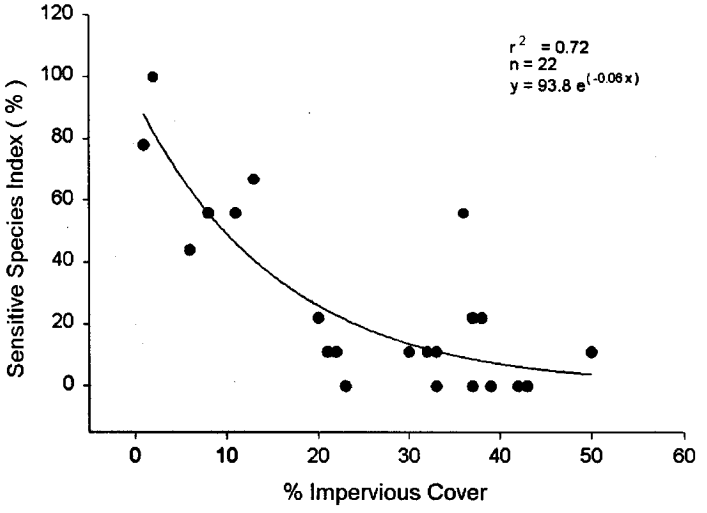


Figure 7 - The effect of impervious cover on the sensitive species of macroinvertebrates using the Sensitive Species Index; see text.



An even stronger relationship was found between impervious cover and the Sensitive Species Index (SSI) (Figure 7). There was almost complete loss of sensitive species once the watershed reached 15% impervious cover (Figure 7). Low density residential development with acre lots has a 25% impervious cover using these procedures. The association between impervious cover and the SSI was particularly strong ($r = 0.78$, $n = 19$) for low density urbanization (< 30% impervious cover).

Conclusions

Aquatic organisms are severely impacted throughout the region. Urbanization appears to be a major nonpoint source of pollution effecting almost all (90%) of the stream miles in the region. Likely stressors include changes in hydrology, water quality, sediment quality, and physical habitat related to urbanization. Further study is needed to define the relative contributions of the various stressors impacting the biota.

A small proportion of stream miles (10%) in the region were found to be comparable to reference conditions for either biological or physical habitat quality. Therefore, approximately 30 miles of nontidal streams in the region still remain in "good" condition after 200 years of European settlement and development. The vast majority of stream miles are impacted by a variety of human activities, with urbanization the most widespread. The protection of rare high quality stream segments and the restoration of numerous impacted segments are management priorities in the region.

Data for biology and habitat assessments can be found in Appendix A.

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