

BUILDING A STRONGER SCIENTIFIC BASIS FOR LAND-USE PLANNING AND WATERSHED MANAGEMENT-- EFFECTS ON WATER QUALITY AND AQUATIC COMMUNITIES IN NJ STREAMS

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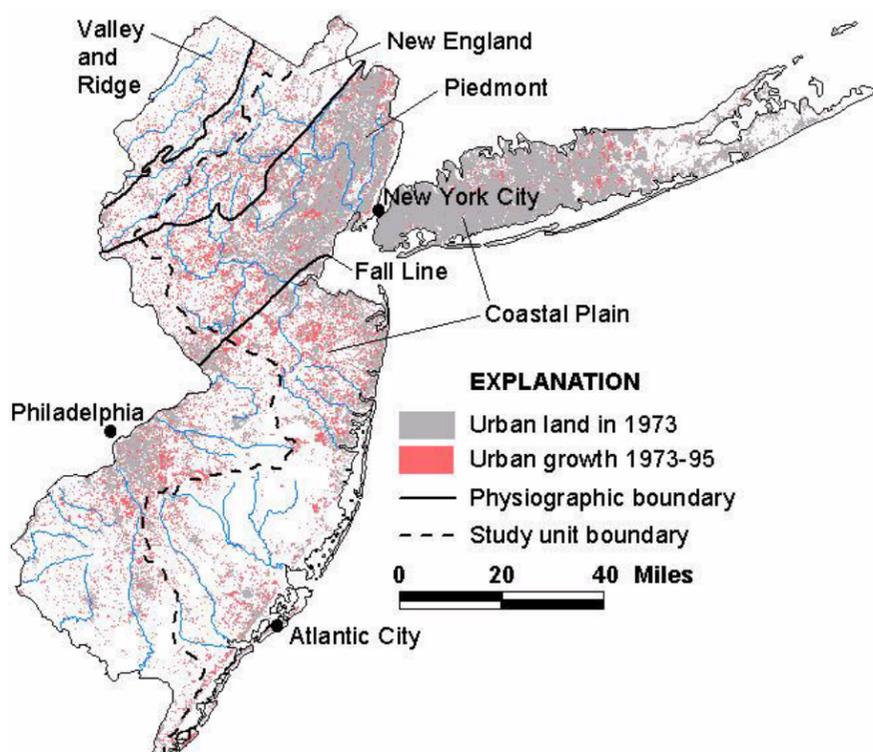
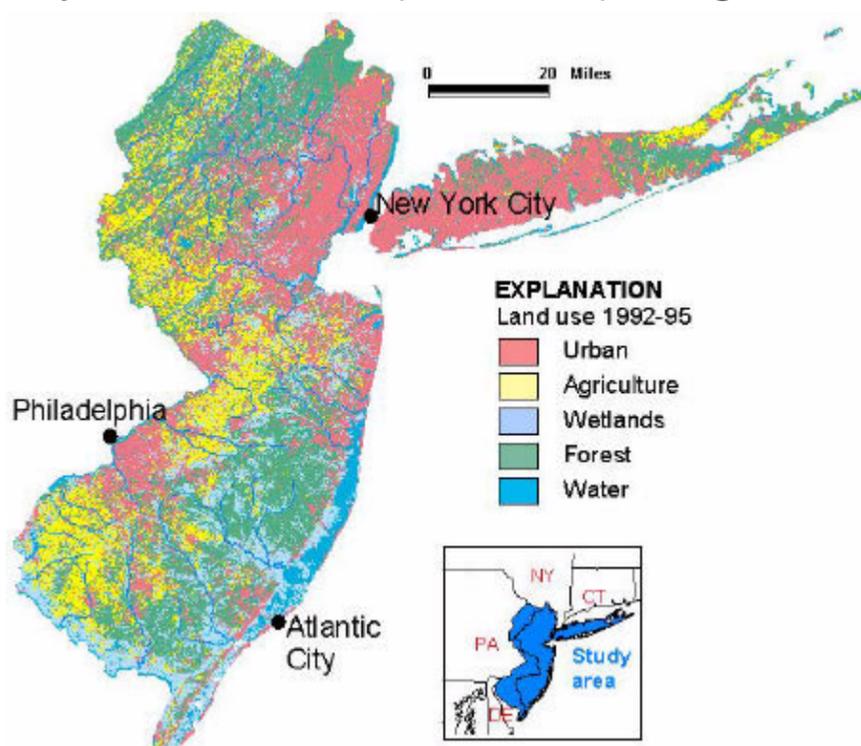
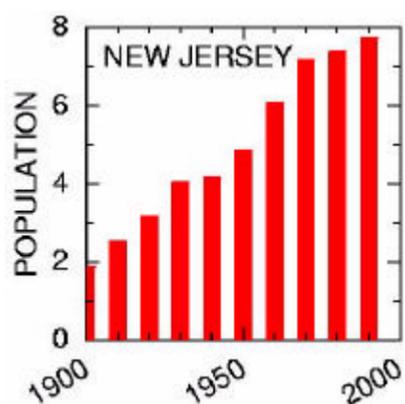
The LINJ NAWQA Study Area

This poster summarizes major findings about the water-quality affects of land use in New Jersey that emerged from the Long Island–New Jersey Coastal Drainages (LINJ) study conducted between 1994 and 1998 by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program.

Although hydrology and geology vary across the study area, chemical and biological data indicate that **land use is the primary differentiating factor for water-quality.**

The study design, therefore, focused on improving our understanding of the specific aspects of urban land use that control water quality and the health of aquatic communities.

Urban land use has grown from 22% of the study area in the early 1970s to 33% in 1995, with a corresponding 11% decrease in agricultural and forest land. Population increased about 9% during the same time period.



Stream Conditions for Fish Have Improved Since the 1970s

Based on differences in the Index of Biotic Integrity (IBI), conditions for fish in streams of the Delaware, Passaic, and Raritan Basins have improved since the 1970s (table 1, Chang and others, 2000).

Of the 88 sites, stream condition:
 Improved at 46%,
 Worsened at 13%,
 Unchanged at 41%.

Reason for improvement:
 Improved treatment of wastewater discharges during the 1980s and to some extent, changes in land-use.

Urban nonpoint influences on impairment are still significant (fig. B below)

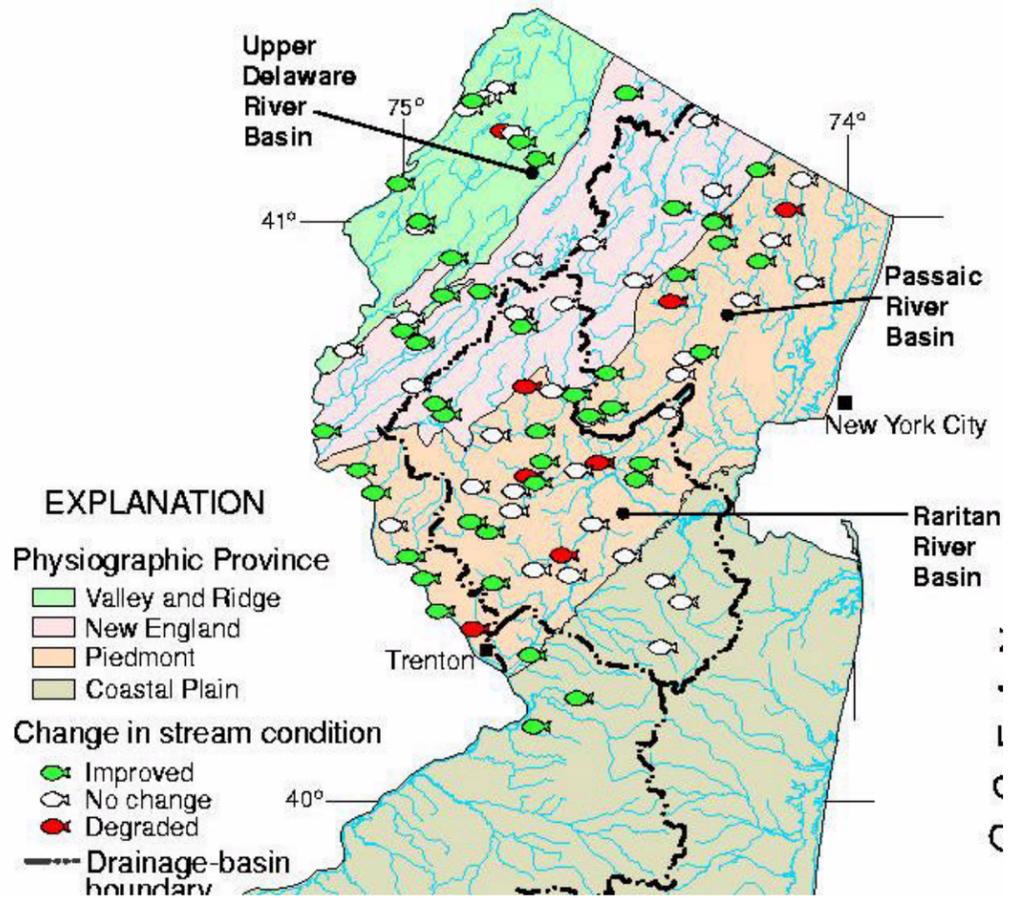


Table 1. Mean basin IBI scores for sampled streams of the Delaware, Passaic, and Raritan River Basins have increased significantly from the 1970s to the 1990s (Chang and others, 2000)

Index	Delaware(32 sites)		Passaic(24 sites)		Raritan(32 sites)	
	1970s	1990s	1970s	1990s	1970s	1990s
Mean Index of Biotic Integrity	34	40	30	35	33	36
Condition rating	fair	good	fair	fair	fair	fair

Index of Biotic Integrity (IBI)—Ten community measures (often called biometrics) based on the number of fish species, feeding habits, abundance, and health are used to evaluate the biological integrity of streams. A score of 1, 3, or 5 is assigned to each community measure on the basis of overall similarity to an appropriate regional reference site, 5 indicating most similar and 1 indicating least similar to reference conditions. Scores for individual community measures at each sampling location are then summed to produce a total score, which is assigned a condition category. The maximum score a site can receive is 50 and the minimum is 10. The four condition categories are excellent (44–50), good (37–43), fair (29–36), and poor (10–28) (Kurtenbach, 1993). The IBI serves as an integrated analysis because individual biological measures provide differing levels of sensitivity to changes in biological condition (Barbour and others, 1999).

NJDEP Ambient Biomonitoring Network (AMNET) is a statewide network of more than 800 aquatic-invertebrate sampling sites that was designed to monitor the condition of aquatic communities in 5 water-management areas on a 5-year rotational basis. This sampling frequency is considered to be realistic for evaluating long-term environmental change. Sampling locations (fig. 7), which were chosen in a stratified-random design to monitor all nontidal streams at approximately 3-mile intervals, include 43 reference (minimally disturbed) sites. Level of community impairment (non-impaired, moderately impaired, and severely impaired) is based on a modification of the USEPA Rapid Bio-assessment Protocol II (Plafkin and others, 1989).

Aquatic Invertebrate and Fish Communities Are Impaired in Urban Streams

Despite the observed improvements in stream conditions since the 1970s related to improvements in waste-water treatment, **fish and invertebrate communities are commonly impaired in urban streams** (figs. A and B; Kennen, 1999).

Invertebrate community impairment was related to:

Total urban land and total wastewater flow upstream of a site.

Total forested area in a basin was a strong mitigating factor, however, and greatly increased the likelihood of having an unimpaired invertebrate community.

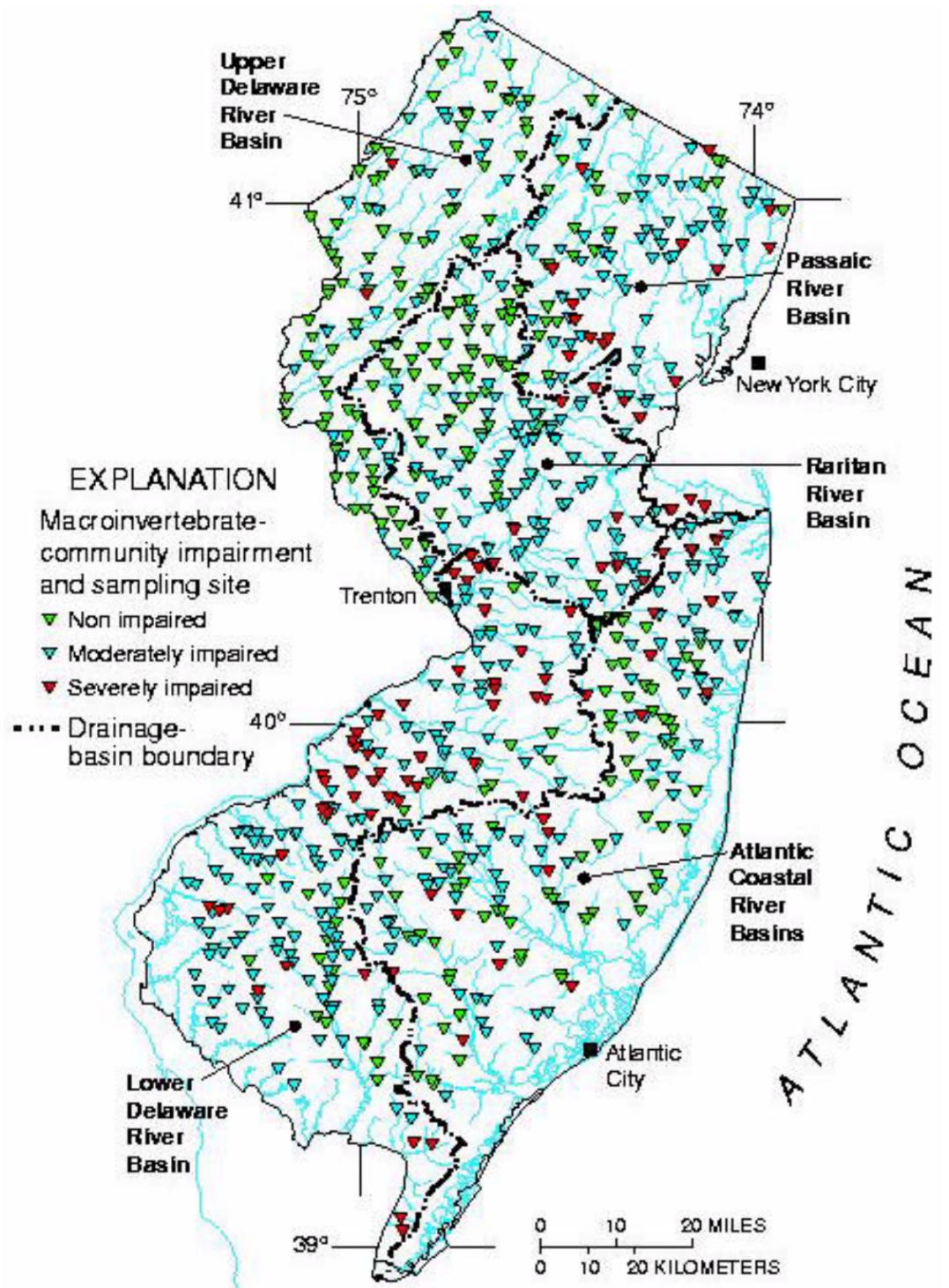


Figure A. Invertebrate communities at more than 780 NJ AMNET sites commonly were moderate to severe impairment in higher density urban areas.

A poor fish-community IBI score was related to:

Total urban land upstream and total human population in proximity to the sampling site.

The presence of forest in a basin again was a mitigating factor.

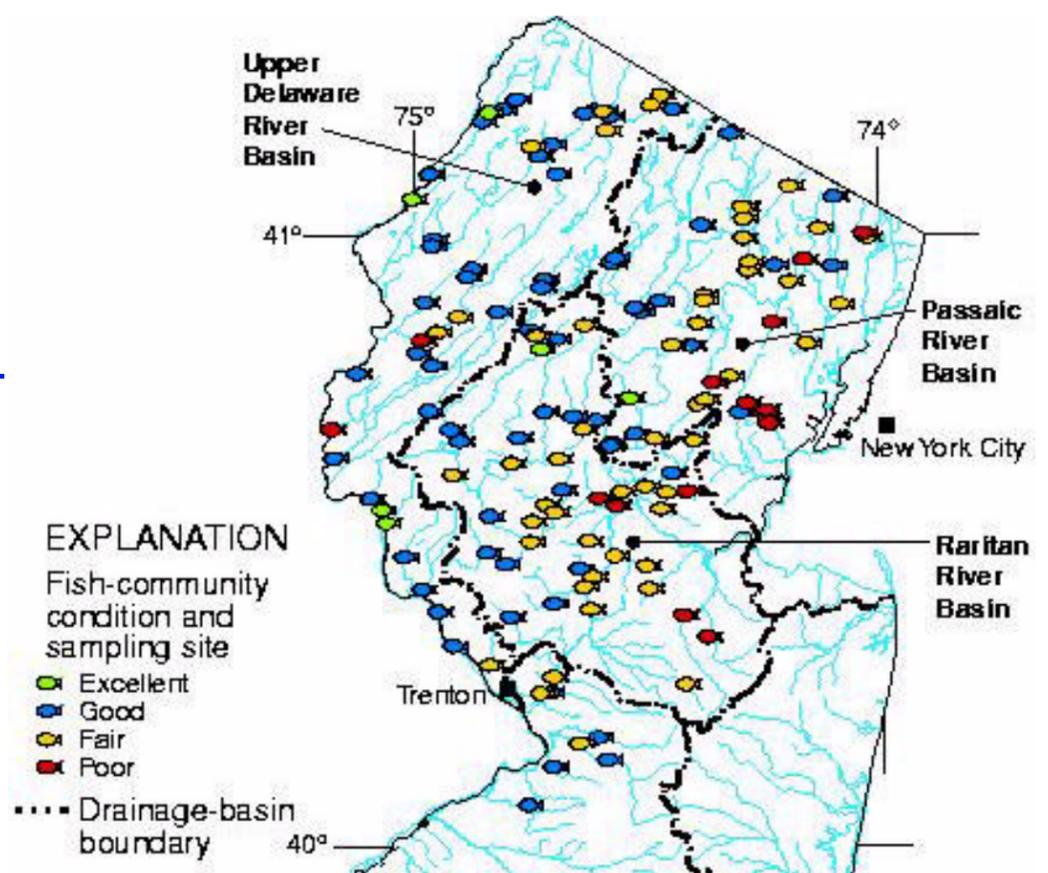
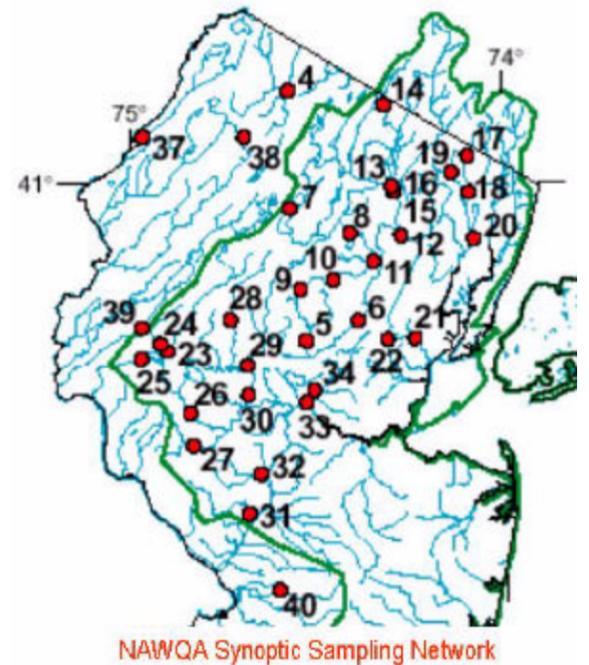


Figure B. Fish-community IBI scores at more than 150 sampling sites in northern NJ indicate that streams in urban areas are in poor to fair condition (data from Kurtenbach, 1993).

Characteristics of Urban Landscapes That Affect Aquatic Community Health

Data on fish, invertebrate, and algal communities in 36 NJ streams were integrated with about 400 environmental variables to assess the effects of the urban landscape on water quality. Watersheds were chosen to represent an urban land-use gradient, which ranged from 3 to 96% urban and from 15 to 180 mi² in drainage area.



Changes in aquatic community structure were statistically related to environmental variables along the urban gradient (table 3 bottom of next column).

Changes in streamflow, impervious road area, and population density were related to impairment in all 3 aquatic communities (negative in table 3). Specifically, changes in hydrologic factors (such as decreases in base flow and increases in peak discharge and flow variability) were found to influence the types and condition of aquatic communities present in a stream, in large part, by the way these changes in flow affect stream habitat.

The presence of a cobble substrate was a factor contributing to healthier fish and invertebrate communities (positive in table 3). Changes in the substrate characteristics of urban streams are related to increases in flow, channel erosion, and sedimentation common to minimally controlled urban storm runoff.



Point-source flow, urban growth 1986-95, and impervious nonroad area were related to invertebrate impairment only (negative in table 3).

Changes in water-use and wastewater distribution practices can lead to reductions in base flow and greatly influence the suitability of a stream for many types of organisms (Klein 1979), especially aquatic invertebrates. For example, the difference in wetted habitat for median-flow conditions (upper photo) and low-flow conditions (bottom photo) at Neshanic River at Reaville, NJ, is substantial, although not solely related to human activities.



The [area of forest and wetlands](#) was positively related to invertebrate community health (table 3). Forests and wetlands play a major role in maintaining a healthy supply of water, food, and habitat for disturbance-intolerant and highly desired species. Forest and wetlands can help mitigate the undesirable effects of urban development. Proximity of forest (for example, riparian areas) to the sampling site was also an important factor.

Table 3. Environmental factors that were highly related to impairment of fish, aquatic-invertebrate, and algal communities along an urban land-use gradient. Green shading indicates factors that were more favorable to healthy aquatic communities and red shading indicates factors that were less favorable. [NS, No statistically significant effect on aquatic community]

Watershed characteristic	Response of aquatic community		
	Fish	Aquatic invertebrates	Algae
Area of forest and wetlands	NS	Positive	NS
Ability to maintain base flow	NS	Positive	NS
Percentage of cobble substrate	Positive	Positive	NS
Median sulfate concentration	NS	Positive	Positive
Median total phosphorus concentration	Negative	NS	Positive
Mean annual flood	Negative	Negative	Negative
Flashiness of streamflow	Negative	NS	NS
Impervious area, road area only	Negative	Negative	Negative
Impervious area, nonroad area only	NS	Negative	NS
Population density	Negative	Negative	Negative
Total urban area in 1986	Negative	NS	NS
Urban area growth from 1986 to 1995	NS	Negative	NS
Commercial and industrial area in 1986	NS	Negative	Negative
Total point-source flow	NS	Negative	NS

Natural Differences Exist in the Invertebrate Community Structure Across NJ

Aquatic invertebrate communities in southern NJ are distinctly different from those in the north because of natural differences in environmental and physical conditions (table 2). This is why the NAWQA urban gradient study focused its efforts and resources in northern NJ.

Table 2. Differences in aquatic-invertebrate communities in 43 reference streams between northern and southern New Jersey can be explained by natural differences in environmental conditions		
	Northern NJ	Southern NJ
Most abundant aquatic invertebrates	Mayflies, stoneflies, caddisflies, and riffle beetles	Worms, clams, midges, black flies, caddisflies, and stoneflies
Environmental characteristics	Steeper channels and higher diss. O2 content	Low pH and low dissolved solids and nutrient content
Streambed characteristics	Mainly rock and cobble	Mainly sand and other fine sediments

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Implications of Findings for the Management of Water and Ecological Resources

Stream conditions for fish appear to have improved some since the 1970s largely as a result of wastewater-treatment-plant upgrades implemented under provisions of the Clean Water Act (CWA).

However, changes in the natural flow of streams, habitat degradation, reduction in biological diversity, and a shift toward species more tolerant of disturbance are associated with urban and suburban development. Given the prospect for increasing population growth in the region, land-use changes associated with urban development will continue to have a measurable effect on water quality and aquatic communities.

What might we do to help?

Encourage a closer linkage and integration of land-use planning and watershed-management goals and strategies, to further awareness and ideas that favor improvement of water and environmental quality.

Apply techniques that increase recharge and otherwise reduce runoff in new or existing developments to increase stream base flow and reduce streamflow variability, both of which would benefit aquatic communities. Increased aquifer recharge also would benefit water supply if the quality of that recharge is not impaired.

Promote policies that prevent the loss of or restore forest and wetland function and area, especially in riparian corridors, to moderate the effects of development and provide improved habitat for plants and animals. For example, by providing shade, natural organic detritus, diverse habitat, a dampening of runoff, and filtration of contaminants, riparian forest and wetland areas playing a major role in maintaining a healthy supply of water, food, and habitat that favors disturbance-intolerant and highly desired aquatic species.

Establish performance measures and increase vigilance in terms of monitoring and assessment of water and related resources to measure progress, especially as related to the performance of lower intensity development practices and techniques.



New urban areas commonly are displacing agricultural and (or) forest land in the study area. Specifically, urban land area has grown from 22% of the study area in the early 1970s to 33% in 1995, with a corresponding 11% decrease in agricultural and forest land.

Studies to Support the Scientific Basis for Land-Use Planning and Watershed Management

Overall goal is to provide a stronger scientific basis for the development of NJ land-use planning and watershed management strategies that mitigate the effects of urban development on aquatic ecosystems.

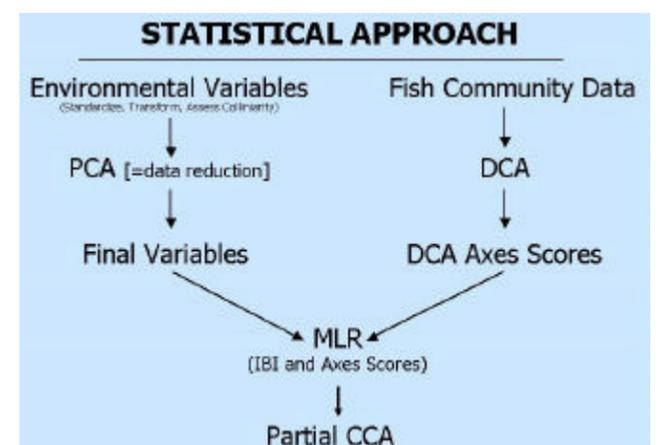
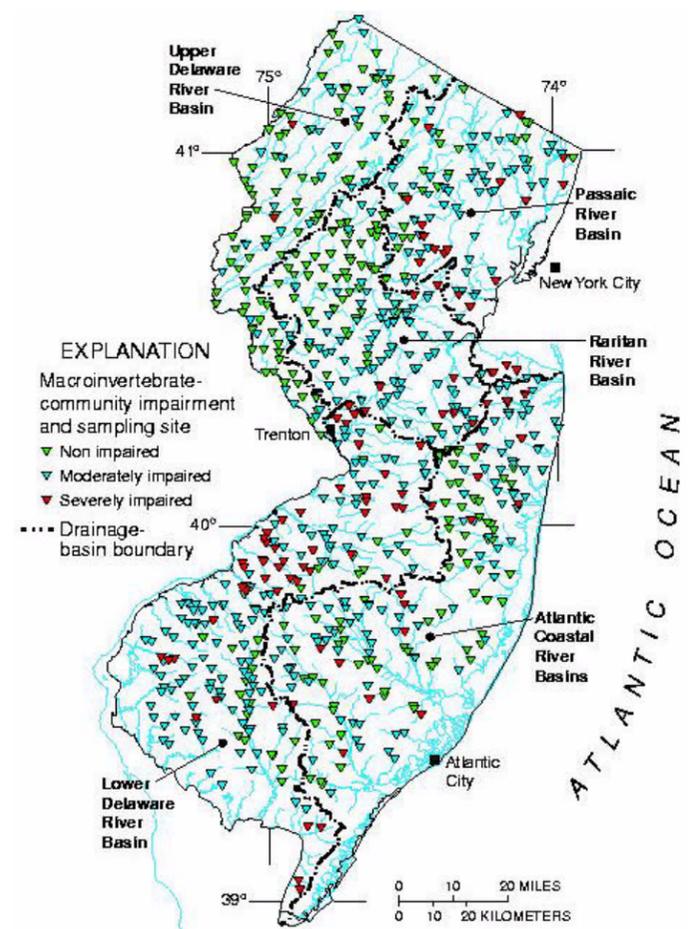
Cooperative study with the NJ Department of Environmental Protection (NJDEP)

Title: Improving watershed indicators as a basis for developing realistic stream restoration goals

Problem: Over 500 of 800 AMNET biological monitoring sites have indicated impairment.

Goal: Assessment of the dominant environmental factors contributing to 'confirmed' impairment is needed to assist development of stream restoration goals statewide.

Approach: The significance of changes in hydrology require a modeling analysis of flow characteristics (TOPMODEL and impervious area) for the 800 sites. Then, a rigorous statistical evaluation (regression and multivariate) of major controlling factors contributing to impairment will be made at multiple levels of data stratification (land use, basin size, and physiography). This evaluation is needed to better link the spatial aspects of watershed sources with observed biological affects. Finally, an approach to translate these findings into viable management options will be developed and piloted.



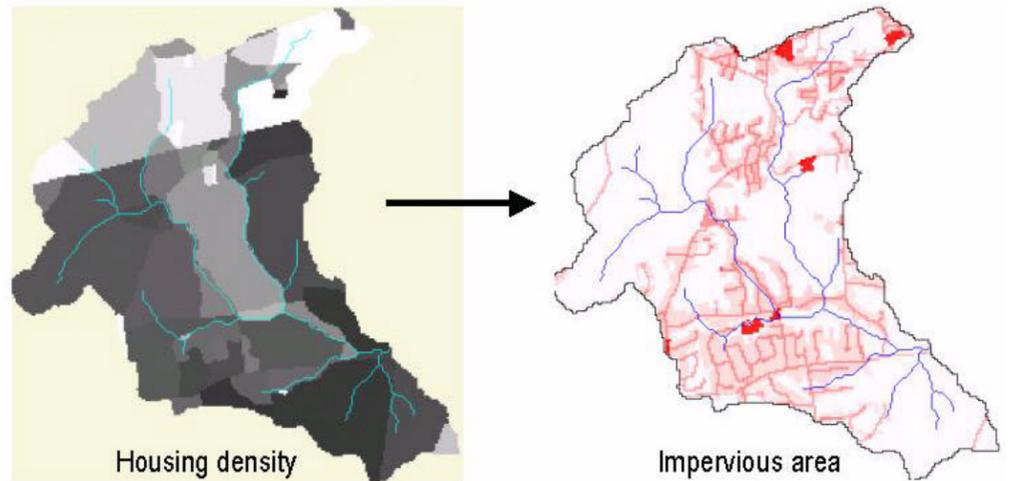
Cooperative study with the NJ Office of State Planning (OSP)

Title: Modeling changes in runoff and ecological characteristics of New Jersey watersheds in response to alternative land-use scenarios

Problem: OSP is looking to build a tool to help citizen planners to more effectively use environmental information in their land-use planning process. The toolbox would provide (1) visualization of watershed concepts, environmental data and status, and information on how to prevent environmental impact, (2) point and click placement of future development by citizen planners using environmental information as a guide, and (3) a relative evaluation of potential effects of planned development with behind the scene linkages to scientific principles and findings. Hopefully, a stronger local buy-in to state regulations and increased development of effective local ordinances will result.

Goal: to integrate hydrologic and aquatic community research findings into OSP planning toolbox (decision support system).

Example environmental application: From a 2020 county or municipal plan, OSP model outputs of population and housing density can be used with current equations to predict impervious surface area. Stream flow changes (TOP-MODEL) and biological impacts (regression equations) can then be estimated from the location and amount of population and impervious area changes. The approach should be applicable to watershed areas greater than about 5 square miles in size and population growth greater than 5-10%. Feedback on relative impacts of different plans can be used to test local, region, or statewide policies. In later iterations, other water-quality aspects can be added.



Basis and approach: Integrate the results of the watershed indicators study above into the tool, assist in defining approaches for the presentation, visualization, and evaluation of the data generated in a manner that can be understood and applied by prospective users, and assist in defining those 'informational' maps that will help planners define, visualize, evaluate, and hopefully avoid or minimize the ecological, hydrologic, and other impacts of planned development.