

Effects of flow alteration on ecological health of streams across the Atlantic Highlands Ecoregion

U.S. Geological Survey: New England and New York Water Science Centers in cooperation with the National Water-Quality Assessment (NAWQA) Program

Background

Streamflows are altered throughout the world for hydropower, flood protection, water withdrawals, wastewater return flows, and other societal needs. However, changes to the natural flow regime can markedly affect the biological, physical, and chemical conditions of streams and adjacent riparian zones. Many aquatic organisms require specific temperature ranges that are timed with certain streamflows to complete their life cycles. For example, storing and releasing stream water with engineered controls alters the natural flow patterns and water temperatures that are necessary for successful reproduction and growth by species such as native brook trout (*Salvelinus fontinalis*). Flow alteration, therefore, often causes a thermal-regime shift in a stream, and this linked effect will typically disrupt the natural species composition and ecological function of aquatic biological communities.

In the northeastern United States, increased demand for water, coupled with expectations of increased climate variability, will likely require changes in water management strategies that will affect stream ecosystems in ways that are not yet fully understood. Gaining a better understanding of relations between ecologic condition and alterations of streamflow and thermal regimes will provide a stronger scientific basis for sound management of these important resources in light of future changes in water use, water availability, and climate. To address these concerns, the USGS is initiating a regional study to investigate flow-ecology relations in the Atlantic Highlands Ecoregion.

Study Area

The Atlantic Highlands Ecoregion, located in the mountainous areas of the northeastern U.S., contains headwaters of numerous major rivers in portions of eight states (figure 1). This ecoregion has some of the largest expanses of contiguous forest in the eastern U.S. with streams that provide critical habitat for sensitive native aquatic species, including eastern brook trout and endangered freshwater mussels.

Flow alteration is one of the primary disturbances to streams in the Atlantic Highlands (others include acidification, mercury contamination, and climate variation). Even among the relatively forested watersheds in this ecoregion, flows of some streams have been altered to meet demands for water supply, power generation, flood control, wastewater treatment, and recreation. For example, the mountain streams in the upper Delaware River Basin are managed to provide drinking water to over 15 million people, primarily in the New York City metropolitan area.

Across the Atlantic Highlands, the USGS has streamgages established on more than 200 streams (fig. 1), some with unaltered (natural) flows, and others with various degrees of flow alteration. Hydrologic data from this streamgage network will be used to quantify how stream hydrology is affected by flow alteration. These results, when associated with the condition of streams that have primarily forested watersheds and sensitive biological communities, provide the elements for a scientifically robust study to assess how flow alteration affects the hydrology and ecology of streams. In addition, findings from the study can be linked to complementary research and assessment activities that are occurring across the Atlantic Highlands.

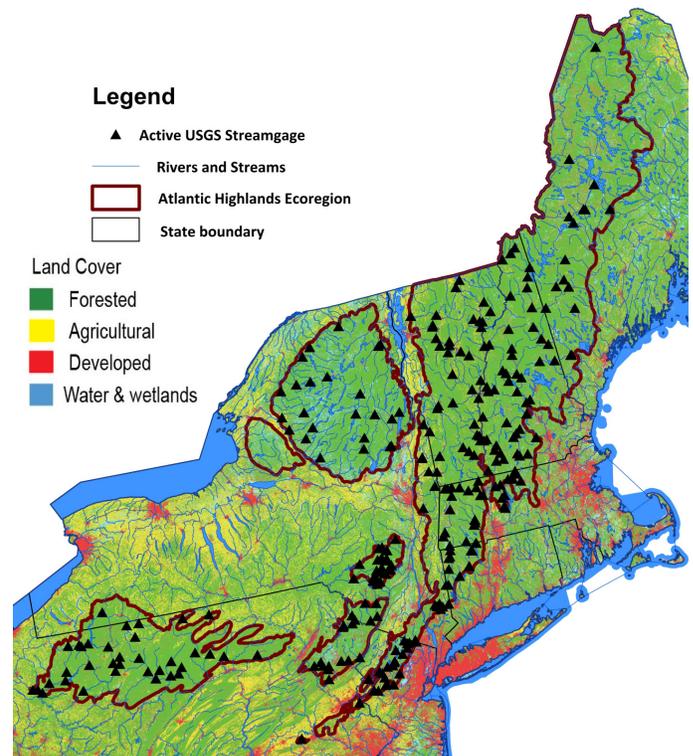


Figure 1. Active USGS streamgages (triangles) in the Atlantic Highlands Ecoregion (outlined in brown), which covers nearly all of NH and VT, eastern NY, and parts of PA, NJ, CT, MA, and ME

Objectives of the Study

The study has two primary objectives:

- (1) Quantify the extent of flow alterations at USGS gaged streams across the Atlantic Highlands Ecoregion, and
- (2) Describe how flow alterations are related to the health of aquatic ecosystems, as indicated by changes in the thermal regime, physical habitat, water chemistry, and aquatic biota.

Approach

Flow alteration, thermal regime, and ecological condition will be quantified at about 70 wadeable streams in the Atlantic Highlands Ecoregion that have active USGS streamgaging stations. Other site selection criteria will include 1) at least 10 years of flow record up to and including the current year, 2) watersheds with minimal developed land and wastewater-treatment returns, and 3) a geographic distribution of locations across the study area. Sites that can be co-located or integrated with other assessment, monitoring, and research efforts will be prioritized. In the summer of 2013, sites will be selected and data loggers installed to record air and water temperatures. Other sampling activities are planned for 2014-16.

The general framework of the study will be to quantify the degree of flow alteration at each site by comparing *observed* flows (based on streamgage data from the site) with flows *expected* for unaltered sites (based on streamgage data from reference sites). These flow comparisons result in a series of *observed/expected* ratios (O/E) that are applied to various hydrologic metrics, where a value of 1 indicates unaltered (natural) flows, <1 indicates depleted flows, and >1 indicates inflated flows.

Physical, chemical, and biological data also will be collected at each site, and will include continuous monitoring of air and water temperature, stream and riparian habitat surveys, water quality parameters, and biological community assessments (aquatic macroinvertebrates currently planned, with options for fish and algae). These data will be correlated to the O/E values across the site network to help identify how stream health is affected by the degree of streamflow alteration in the Atlantic Highlands. For example, results from a flow-ecology study in the Rocky Mountains of the U.S. indicated that flow alteration likely caused a shift in the stream's thermal regime, which in turn resulted in a loss of sensitive macroinvertebrate species and a decline in stream health (Carlisle, 2012). Similarly, interactions among ecological factors associated with flow alterations are important to understand in the Atlantic Highlands so that resource managers are prepared for future water demands, especially when considering the uncertainty of climate variations.

Potential application of study results

Models developed to predict the ecological effects of streamflow and thermal alteration can be used by states and other entities in the management of streams to balance societal and ecological needs. Findings from the study will help address questions related to current conditions as well as provide guidance for long-range planning:

- What are the optimal flow and temperature conditions for various aquatic species, and what changes in biological communities are expected when flow and thermal regimes shift?

- What percentage of stream base flow should be maintained to support water quality standards for protection of aquatic life?
- How can water management be optimized to meet human needs while minimizing effects to ecological health of downstream waters?
- How would various future climate-change and water-use scenarios affect streamflow, thermal regime, and stream health?

Support from the National Water Quality Assessment Program

Congress established the USGS National Water-Quality Assessment Program (NAWQA) two decades ago as a source for information on the quality of the Nation's surface water and groundwater, how water quality changes over time, and how natural factors and human activities affect water quality. NAWQA began its third decade in 2013 with a focus on goals that are based on perspectives from past accomplishments, as well as current water-quality issues facing the Nation. An important goal for NAWQA during the upcoming decade is to identify the effects of flow alteration on aquatic ecosystems across the U.S., and consequently, NAWQA is providing partial funding for the Atlantic Highlands flow-ecology study. Also, NAWQA's involvement provides experience gained from other USGS streamflow investigations to the Atlantic Highlands study.

Additional opportunities

Linking the flow-ecology study with other assessment, monitoring, and research activities in the northeast is a high priority for the USGS. Partnerships with the USGS will help supplement resources to collect data, share information, and promote scientific understanding in the region. To facilitate collaborations, the USGS is soliciting input and cooperator support from interested parties (such as state and federal agencies, academic institutions, and non-governmental organizations) on issues of ecological importance associated with flow alteration and areas of complementary research.

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