pH and Acid Anion Time Trends in Different Elevation Ranges in the Great Smoky Mountains National Park

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ABSTRACT: Quarterly base flow water quality data collected from October, 1993 to November, 2002 at 98 stream sites in the Great Smoky Mountains National Park were used to stepwise multiple linear regression models to analyze pH, acid neutralizing capacity (ANC), and sulfate and nitrate long-term time trends. The potential predictor variables included cumulative Julian day, seasonality, elevation, basin slope, stream order, precipitation, snowpack streamflows, geology, and acid depositional fluxes. Modeling revealed statistically significant decreasing trends in pH and sulfate with time at lower elevations, but generally no long-term time trends in stream nitrate or ANC. The best forecasting models were chosen based on maximizing the r^2 of a holdout data set. If conditions remain the same and past trends continue, the forecasting models suggest that 50.0% of the sampling sites will reach pH values less than 6.0 in less than 10 years, 63.3% in less than 25 years, and 96.7% in less than 50 years. The pH forecasting models explain 69% of the variability in the holdout data.

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CE Database subject headings: Acid rain; pH; Regression analysis; Time series analysis; Water quality; Monitoring; Elevation; Mountains.

Introduction

The Great Smoky Mountains National Park (GRSM) has more than 1,000 km (1,360 mi) of streams, including five streams designated as Outstanding National Resource Waters. GRSM streams support a great number of aquatic species, and its trout fisheries are considered some of the best in the eastern United States. The GRSM also receives some of the highest amounts of acid deposition amongst all national parks, and the pH of precipitation (Shubzda et al. 1995) is about 4.5 in the GRSM region (USEPA 1998). The acidic deposition raises serious concerns for stream impairment because the GRSM's geology lacks significant buffering capacity [90% of all monitored stream sites have acid neutralizing capacity (ANC) less than 200 μeq/L and 50% have less than 50 μeq/L and 21% have a base flow pH less than 6.0]. In comparison, Driscoll et al. (2001) stated that aquatic biota living in surface waters having a pH of less than 6, ANC less than 50 μeq/L, or aluminum concentration greater than 2 μmol/L are at risk from surface water acidification. Sulfate and nitrogen are closely associated with acid deposition. Indeed, at least one high elevation watershed in the GRSM is believed to be in Stage 2 nitrogen saturation (Stoddard 1994), with elevated nitrate concentrations in those streams year round (Nodvin et al. 1995, van Miegroet et al. 2001). Importantly, some GRSM streams that once supported native brook trout populations as recently as 20 years ago no longer do, and acid deposition is suspected to have contributed to their extirpation.

Because of the potential impact of acid deposition, long-term base flow stream water quality monitoring began in 1993. Data are available from a core of 98 stream sites with enough historical record to assess long-term water quality trends (Fig. 1). The objectives of this study were to:

1. Determine if pH, ANC, nitrate, and sulfate are improving or degrading with time in select GRSM streams, i.e., to determine how much of the variability in water quality is explained by long term/time trends (hereafter referred to as time trends).
2. Determine if there are differences in time trends for pH, ANC, nitrate, and sulfate within different elevation zones.
3. Determine if statistically significant forecasting models for stream pH, ANC, nitrate, and sulfate can be developed.

Background

The 1970 and 1990 Amendments of the Clean Air Act (CAA) have resulted in declines of power plant emissions and conse-

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