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Is headwater chemistry predictable from downstream observations?

J. Temnerud (1), J. Fölster (1), I. Buffam (2), H. Laudon (3), M. Erlandsson (1), and K. Bishop (1)

(1) Swedish University of Agricultural Sciences, Department of Aquatic Science and Assessment, Uppsala, Sweden (johan.temnerud@vatten.slu.se), (2) University of Wisconsin-Madison, Department of Zoology, Madison, USA, (3) Swedish University of Agricultural Sciences, Department of Forest Ecology and Management, Umeå, Sweden

The length of all perennial streams in Sweden is estimated at 530 000 km, with 78% of the stream length having catchment areas under 2 km^2. There is an interest in assessing the quality and sensitivity of these headwaters, but small streams (catchment size < 2 km^2) usually have larger chemical and hydrological variation than larger streams. This study tests the hypothesis that downstream monitoring data can be used to predict the distribution of chemistry in headwaters.

Data from 17 Swedish synoptic catchment surveys was used, covering 4 degrees of latitude. Samples were taken between 2000 and 2008, at different times of the year including all seasons and one snow melt episode. The median size of the catchments at the outlets was 72 km^2 (range 36-127 km^2), and the median number of headwater streams surveyed in each catchment was 28 (range 14-55), with an average catchment size of 0.57 km^2 (range 0.03-2 km^2). All catchments consist mainly of forest (>80%), with forest mostly coniferous dominated by Norway spruce (Picea abies). Mires and small lakes make up most of the remaining parts of the catchments, which have only minimal developed or agricultural areas. The water chemistry parameters analysed were pH, total organic carbon (TOC) and acid neutralizing capacity (ANC).

Correlations between the outlets and their headwaters were evaluated, both for the median chemistry and the variability, here expressed as the interquartile range (IQR = 75th-percentile minus 25th-percentile). The highest correlation between the outlet and headwaters was found for ANC (r^2 = 0.94 for the median and r^2 = 0.75 for the IQR, both $p < 0.001$), followed by TOC (r^2 = 0.43, $p < 0.05$, and r^2 = 0.15, p = 0.07, respectively). Using all pH data no significant correlations were observed. Omitting the spring flood synoptic data from the evaluation the biologically important pH had a similarly strong correlation between outlet pH and median headwater pH (r^2 = 0.60, $p < 0.001$) but still no correlation with IQR. All correlations were positive, i.e. higher values at the outlet were associated both with higher median values as well as higher variability (IQR).

There was also a pattern of changing chemistry with distance downstream in most catchments. Median TOC was higher in headwaters than at the outlets, while ANC and pH were lower in headwaters, compared to the outlets. The proportionality between headwaters and outlet was such that the headwater median was 59% of the outlet ANC, 89% of outlet pH and 134% of the outlet TOC.

These preliminary results suggest that downstream chemistry will provide a valuable tool in characterizing the range of chemistry experienced in the headwater streams which make up the bulk of any stream network. Current lines of research include further evaluating whether GIS information on amount of lakes, mires etc. in these systems could improve the prediction of headwater chemistry parameters, and make it possible to advance from describing the distribution to assessing specific streams.