Ecosystems (1998) 1: 310–320

ECOSYSTEMS

Hydrologic Variability of Small, Northern Michigan Lakes Measured by the Addition of Tracers

Jonathan J. Cole* and Michael L. Pace

Institute of Ecosystem Studies, Cary Arboretum, Millbrook, New York 12545, USA

ABSTRACT

The hydraulic residence time (or flushing rate of water) is a key variable for any aquatic ecosystem and is used in many types of models and calculations. Rather than being measured directly, the hydraulic residence time is usually inferred from estimates of watershed size, precipitation, and water yield. Such estimates can be problematic in any environment but are especially so in environments in which flat or complex topography makes delineations of mapped watershed boundaries difficult to discern. We added lithium bromide, (LiBr) to three small seepage lakes in the flat topography of the Upper Peninsula of Michigan to provide an independent estimate of the water residence time. Water residence time [volume/(outflow + evaporation)] averaged 921 ± 381 (SD) days among lakes and years and ranged from 400 to 1661 days at the extremes. This variation was not clearly related to year-to-year variation in precipitation, which was relatively constant [0.26 ± 0.06 (SD) cm day $(d)^{-1}$]. The addition of the tracer (along with measurements of lake volume) enabled us to estimate, independent from other hydrologic information, the flow of water leaving the lakes in seepage plus surface outflow. This value, in conjunction with measurement of precipitation and evaporation, enabled us to calculate complete water budgets for these lakes. Among lakes and years, the groundwater input averaged 0.48 ± 0.36 cm d^{-1} and accounted for 57% ± 19% of total water input. This estimate was larger by 150% than that obtained by multiplying precipitation (minus estimated evapotranspiration) times a mapped value of the watershed areas. Our analysis enables us to calculate the relative significance of groundwater and precipitation for solutes such as phosphorus, hydrogen ion, and dissolved organic carbon.

Key words: hydraulic residence time; hydrologic variability; lakes; Michigan; tracers; watershed.