A biogeochemical model for metabolism and nutrient cycling in a Southeastern Piedmont impoundment

Xiaoqing Zeng 1, Todd C. Rasmussen *, M. Bruce Beck, Amanda K. Parker 2, Zhulu Lin 3

Warnell School of Forest Resources, The University of Georgia, Athens, GA 30602-2152, USA

Received 22 October 2004; received in revised form 15 February 2005; accepted 9 May 2005

Available online 8 August 2005

Abstract

While non-point nutrient loads are important determinants of biological productivity in Southeastern Piedmont impoundments, productivity can be attenuated by concomitant sediment loads that reduce the biological availability of these nutrients. A biogeochemical model is proposed that explicitly accounts for the effects of sediment—nutrient interactions on multiple components of phytoplankton metabolism dynamics, including algal photosynthesis and respiration, pH, carbonate speciation, dissolved oxygen, and biochemical oxygen demand. Sediment—nutrient interactions relate nutrient uptake and release to pH, sediment oxygen demand, sediment organic matter, and iron. pH is a state variable in our model, affects sediment—nutrient adsorption, and constrains model parameters. The model replicates water quality observations in a small Southeastern Piedmont impoundment and suggests that pH-dependent sediment—nutrient adsorption dominates both orthophosphate and ammonium dynamics, with phosphate adsorption being controlled by ligand exchange to iron oxides, and ammonium adsorption being controlled by the cation exchange capacity. Sediment organic matter accumulation and decay also affects nutrient availability, and may explain the long-term increase of hypolimnetic dissolved oxygen deficit in Lake Lanier, a large Southeastern Piedmont impoundment.

© 2005 Elsevier Ltd. All rights reserved.

Keywords: Lake biogeochemistry; pH—sediment—nutrient interactions; Lake metabolism; Southeastern Piedmont

1. Introduction

Phosphorus (P) and nitrogen (N) are essential elements affecting the trophic status of lakes. At elevated concentrations, these nutrients generally lead to increased biological productivity and a tendency towards lake eutrophication (Daniel et al., 1998). The principal effects of eutrophication include increased algal growth, hypolimnetic oxygen depletion, increased pH variation, and food-chain alteration. Given that nutrients can be removed from point-source discharges — typically municipal wastewater treatment plants — increased attention has been placed on curbing non-point nutrient sources (Carpenter et al., 1998). Of special relevance to the Southeastern Piedmont, soil particles mobilized in surface runoff from erodible soils may bear significant loads of phosphorus.

The Piedmont region of the Southeastern United States has a humid, warm-temperate climate. The region’s abundant rainfall generates runoff which — when combined with the region’s deeply-weathered and highly-erodible soils — carries large amounts of