Benthic biogeochemical cycling, nutrient stoichiometry, and carbon and nitrogen mass balances in a eutrophic freshwater bay

Klump, J. Val, Sharon A. Fitzgerald, James T. Waples

Limnol. Oceanogr., 54(3), 2009, 692-712 | DOI: 10.4319/lo.2009.54.3.0692

ABSTRACT: Green Bay, while representing only ~7% of the surface area and ~1.4% of the volume of Lake Michigan, contains one-third of the watershed of the lake, and receives approximately one-third of the total nutrient loading to the Lake Michigan basin, largely from the Fox River at the southern end of the bay. With a history of eutrophic conditions dating back nearly a century, the southern portion of the bay behaves as an efficient nutrient and sediment trap, sequestering much of the annual carbon and nitrogen input within sediments accumulating at up to 1 cm per year. Depositional fluxes of organic matter varied from ~0.1 mol C m22 yr21 to >10 mol C m^{-2} yr^{-1} and were both fairly uniform in stoichiometric composition and relatively labile. Estimates of benthic recycling derived from pore-water concentration gradients, whole-sediment incubation experiments, and deposition-burial models of early diagenesis yielded an estimated 40% of the carbon and 50% of the nitrogen recycled back into the overlying water. Remineralization was relatively rapid with ~50% of the carbon remineralized within ~15 yr of deposition, and a mean residence time for metabolizable carbon and nitrogen in the sediments of 20 yr. On average, organic carbon regeneration occurred as 75% CO_2, 15% CH_4, and 10% dissolved organic carbon (DOC). Carbon and nitrogen budgets for the southern bay were based upon direct measurements of inputs and burial and upon estimates of export and production derived stoichiometrically from a coupled phosphorus budget. Loadings of organic carbon from rivers were ~3.7 mol m^{-2} yr^{-1}, 80% in the form of DOC and 20% as particulate organic carbon. These inputs were lost through export to northern Green Bay and Lake Michigan (39%), through sediment burial (26%), and net CO_2 release to the atmosphere (35%). Total carbon input, including new production, was 4.54 mol m^{-2} yr^{-1}, equivalent to ~10% of the gross annual primary production. Nitrogen budget terms were less well quantified, with nitrogen export ~54% of total inputs and burial ~24%, leaving an unquantified residual loss term in the nitrogen budget of ~22%.