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Modeling the response of primary production and sedimentation to variable nitrate loading in the Mississippi River plume

Rebecca E. Green (1), Greg A. Breed (2), Michael J. Dagg (3), Steven E. Lohrenz (4)

(1) Ocean Sciences Division, Naval Research Laboratory, Stennis Space Center, Mississippi, USA, (2) Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada, (3) Louisiana Universities Marine Consortium, Chauvin, Louisiana, USA, (4) Dept. of Marine Science, The University of Southern Mississippi, Stennis Space Center, Mississippi, USA (rgreen@nrlssc.navy.mil / Phone: 228-688-5576)

Increases in nitrate loading to the Mississippi River watershed during the last 50 years are considered responsible for the increase in hypoxic zone size in Louisiana-Texas shelf bottom waters. There is currently a national mandate to decrease the size of the hypoxic zone to 5,000 km^2 by 2015, mostly by a 30% reduction in annual nitrogen discharge into the Gulf of Mexico. We developed an ecosystem model for the Mississippi River plume to investigate the response of organic matter production and sedimentation to variable nitrate loading. The nitrogen-based model consisted of 9 compartments (nitrate, ammonium, labile dissolved organic nitrogen, bacteria, small phytoplankton, diatoms, micro- and mesozooplankton, and detritus), and was developed for the spring season, when sedimentation of organic matter from plume surface waters is considered important in the development of shelf hypoxia. The model was forced by physical parameters specified along the river-ocean salinity gradient, including residence time, light attenuation by dissolved and particulate matter, mixed layer depth, and dilution. The model was developed using measurements of biological biomasses and nutrient concentrations across the salinity gradient, and model validation was performed with an independent dataset of primary production measurements for different riverine NO_3 loads. Based on simulations over the range of observed springtime NO_3 loads, small phytoplankton contributed on average 80% to primary production for intermediate to high salinities ($>$15), and the main contributors to modeled sedimentation at these salinities were diatom sinking, microzooplankton egestion, and small phytoplankton mortality. We investigated the impact of limiting factors on the relationship between NO_3 loading and ecosystem rates. Model results showed that primary production was primarily limited by physical dilution of NO_3, followed by abiotic light attenuation, light attenuation due to mixing, and diatom sinking. Sedimentation was mainly limited by the first three of these factors. Neither zooplankton grazing or plume residence times acted as limiting factors of ecosystem rates. Regarding nutrient reductions to the watershed, simulations showed that about half of the percent decrease in NO_3 load was reflected in decreased plume sedimentation. For example, a 30% decrease in NO_3 load resulted in a 19% decrease in average plume primary production and a 16% decrease in sedimentation. Finally, our model results indicated that the fraction of primary production exported from surface waters is highly variable with salinity (7 - 87%), a finding which has important implications for predictive models of hypoxic zone size that assume a constant value for this ratio.