Optimization-based model of multinutrient uptake kinetics

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ABSTRACT: We present a new, optimization-based model for uptake kinetics of multiple nutrients, which has the same number of parameters (two for each nutrient) as the Michaelis-Menten model. We fit this model and an existing inhibition-based model to data from chemostat experiments at various flow rates (under extreme limitation by both nitrogen [N] and phosphorus [P]) and compared these models and the Michaelis-Menten model to an independent data set for the same species in a chemostat at various N: P input ratios (at constant flow rate). Our model fit the data well, with a slightly higher square error than the much more complex inhibition model. We also successfully applied our model to a data set for a different species under various degrees of vitamin B12- and Plimitation. Our model agrees with measured cell quotas of nonlimiting nutrients when supply ratios differ greatly from the optimal ratio for phytoplankton, whereas the Michaelis-Menten model greatly overestimates the uptake of nonlimiting nutrients at these extreme nutrient supply ratios. The key to our model's success is the optimization of uptake for the limiting nutrient, which results in distinct behavior for limiting versus nonlimiting nutrients, without additional parameters; phytoplankton allocate their internal resources (nitrogen) to optimize uptake of the limiting nutrient, but not in response to changes in ambient nutrient ratios.

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