MASS TRANSFER LIMITS TO NUTRIENT UPTAKE BY SHALLOW CORAL REEF COMMUNITIES

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAI'I IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

OCEANOGRAPHY

DECEMBER 2002

By
James L. Falter

Dissertation Committee:

Marlin J. Atkinson, Chairperson
Carlos F.M. Coimbra
Mark A. Merrifield
Francis J. Sansone
Stephen V. Smith

ABSTRACT

Uptake and assimilation of nutrients is essential to the productivity of coral reefs. Nutrient uptake rates by coral reef communities have been hypothesized to be limited by rates of mass transfer across a concentration boundary layer. The mass transfer coefficient S (m day^{-1}) relates the maximum nutrient flux allowed by mass transfer to the nutrient concentration in the ambient water ($J_{max} = S[N]$). The goal of this dissertation is to determine the maximum rate at which a coral reef flat community can take up nutrients according to mass transfer theory. Nutrient mass transfer coefficients for a Kaneohe Bay Barrier Reef flat community were determined two ways. In the first method, S was estimated from *in situ* measurements of wave-driven flow speeds ($\overline{U}_h$ = 0.08-0.22 m s^{-1}) and the friction coefficient of the reef flat (c_f = 0.22±0.03) using a mass transfer correlation. S calculated from this method was 5.8±0.8 m day^{-1} for phosphate and 9.7±1.3 m day^{-1} for nitrate and ammonium. The second method compared the dissolution of artificial plaster forms (surface area = 0.1-1.0 m^2) of varying roughness scale (0.001-0.1 m) under wave-driven and steady flows ($\overline{U}_h$ = 0.02-0.21 m s^{-1}). Results showed 1) rates of mass transfer were linearly proportional to surface area regardless of roughness scale and flow conditions, and 2) rates of mass transfer were 1.4-2.0 times higher under wave-driven flows (~8-s in period) than under steady flows. Using appropriate surface areas from the plaster dissolution experiments, S for the reef flat community was 7±3 m day^{-1} for phosphate and 12±5 m day^{-1} for nitrate and ammonium. Using the wave enhancement obtained from the plaster dissolution experiments, S could be as high as 9.3±1.3 m day^{-1} and 15.5±2.1 m day^{-1}. The phosphate uptake rate coefficient from flow respirometry for the same reef flat community was 4.5-9 m day^{-1}.

Thus, rates of phosphate uptake by the this community are at the limits of mass transfer. Scaling maximum phosphate uptake rates by the average C:P of benthic autotrophic tissue indicates that net primary production within this community is limited by nutrient uptake.