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Atmospheric dinitrogen fixation by benthic communities of Tikehau Lagoon (Tuamotu Archipelago, French Polynesia) and its contribution to benthic primary production

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Abstract Acetylene reduction rates were measured in lagoonal sediments, cyanobacterial mats and limestone surfaces between 1991 and 1995 at many sites, depths and seasons; all the studied substrata contained cyanobacteria. The acetylene reduction/$^{15}N_2$ fixation ratio was measured for the different communities and varied between 1.8 and 4.8, depending on substratum. Fixation rates were 1.7 to 7 times higher during daylight compared to night-time rates. N_2 fixation rates ranged from 0.4 to 3.9 mg N m^{-2} day^{-1} for the lagoonal sediment/mat communities, and the rate was about 2 mg N m^{-2} day^{-1} for the lagoonal limestone substrata. Total lagoonal benthic N_2 fixation contributed 24.4% of the total nitrogen requirement for the benthic primary production of benthic communities of the lagoon. The input of N_2 fixation by the microbial planktonic communities (including cyanobacteria) of the lagoon, which are highly productive, is unquantified but is likely to be large.

Introduction

The supply of nitrogen and phosphorus has long been a critical question for workers in the field of coral reefs (Odum and Odum 1955; Wiebe et al. 1975). In contrast to the tropical oceanic waters in which they are found (typically oligotrophic waters, characterised by low nutrient concentrations, low plankton biomass, low diversity and low benthic biomass), coral reefs have some of the highest diversities and productivities of any ecosystem known (Hatcher 1990). Coral atolls found in the Indo-Pacific region commonly have a rim surrounding a relatively deep lagoon. In terms of area and volume, the lagoon may often be the most significant component of the system. In the Indo-Pacific region atolls are very important for the economy of such island nations as French Polynesia.

Theoretically, nitrogen can be supplied to coral reefs by at least two processes: (1) exogenous input (such as advection or riverine input – see Furnas et al. 1997) and/or (2) atmospheric dinitrogen fixation by dinitrogen-fixing organisms. The latter process appears to make a major contribution (Wilkinson et al. 1984; Larkum et al. 1988; O'Neil and Capone 1989). Biological dinitrogen fixation is a characteristic feature of many marine benthic photosynthetic communities (Capone 1983; Stal et al. 1984), of which cyanobacteria are the most common dinitrogen fixers (Mague and Holm-Hansen 1975; Potts and Whitton 1977). While many studies of dinitrogen fixation have focused on the hard coral substrata of coral reefs, only rarely have investigations focused on the soft substrata of the lagoon (O'Neil and Capone 1989). This is a serious omission in many coral atolls, where the lagoon surface area may be huge compared to the surface area of hard substrata. In an effort to provide further information we undertook an extensive investigation of dinitrogen fixation in the lagoon of Tikehau (French Polynesia) over a period of 4 years.

In Tikehau lagoon, microphytobenthic communities, dominated by cyanobacteria, are very extensive. They are found on the soft substrata of the lagoon floor (sand and dead coral skeletons and also on pinnacles (large limestone bodies which may rise from the lagoon floor at 15–30 m depth to or near to the surface). In the lagoon of Tikehau subtidal benthic cyanobacterial communities can vary greatly in density, from being invisible to forming very dense mats.

Thus, because N_2 fixation rates are highly dependent on the nature of the substratum (Larkum et al. 1988;

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