THE IMPORTANT ROLE OF ORGANIC MATTER CYCLING FOR THE BIOLOGICAL FIXATION OF CO_2 IN CORAL REEFS

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Abstract-The role of organic matter cycling in increasing biological fixation of CO_2 in coral reef has been studied at Miyako Island in Japan (RITE project of coral reef study).The carbon and nitrogen contents of dissolved and particulate forms of organic matter in coral reef water and in various living organisms were measured. It was found that the concentrations of dissolved and particulate organic matter in the reef are lower than those of open ocean, despite of higher gross productivity area in the world ocean.Calculation from the temporal changes of organic carbon and inorganic carbon in the water column revealed that there is an imbalance between production and consumption.This suggets that carbon accumulates as organic matter in living organisms and the benthic floor of coral reef.

1. INTRODUCTION

The study of the oceanic carbon and nitrogen cycles is fundamental for understanding the biogeochemical cycles of biologically active elements in the ocean. One can not evaluate the possibility for increased biological fixation of CO_2 in coral reefs without an understanding of these cycles. Because they are a key to the problem of the exchange of atmospheric carbon dioxide with the ocean. The rate of carbon dioxide uptake by the ocean is controlled by sea water temperature, carbonate chemistry, biological production and decomposition, and rate of the water mixing. Oceanic carbon and nitrogen cycles are linked strongly with biological activities, and the biodynamic converter between inorganic and organic species in ocean water is driven by biological processes[1][2]. Biological fixation of CO_2 in coral reefs occurs by calcification and organic production, and the rate of calcification which leads to coral reef growth, maintenance, and sediment formation is linked to light through photosynthic production of organic matter. Therefore,the cycling of organic matter is a key factor for determining whether coral reefs are sinks or sources of atmospheric CO_2. In this paper, we would like to report our studying on the significance of the role of organic matter for understanding of carbon balance in coral reef water.

2. SAMPLING AND ANALYTICAL METHOD

We carried out the sampling of water and organisms, and observations in Bora Bay at Miyako Island (25° N, 125° E) in October,'93 , March,'94 and July ,'94 This location is exposed to steady winds and oceanic swell during the summer rainy season (May to October) . Reef substrata is composed of coarse sediments and a consolidated $CaCO_3$ bench. Live corals cover less than 60% of the reef substrata inside the reef flat, and various macrophytes are in evidence. Water sampling was done using a Niskin Sampler (5 liters). Water samples were filtered using GFF filter paper to separate particulate matter from dissolved chemical compounds. We determined dissolved organic carbon and nitrogen using a high temperature catalytic oxidation method (HTCO) [3], and particulate organic carbon

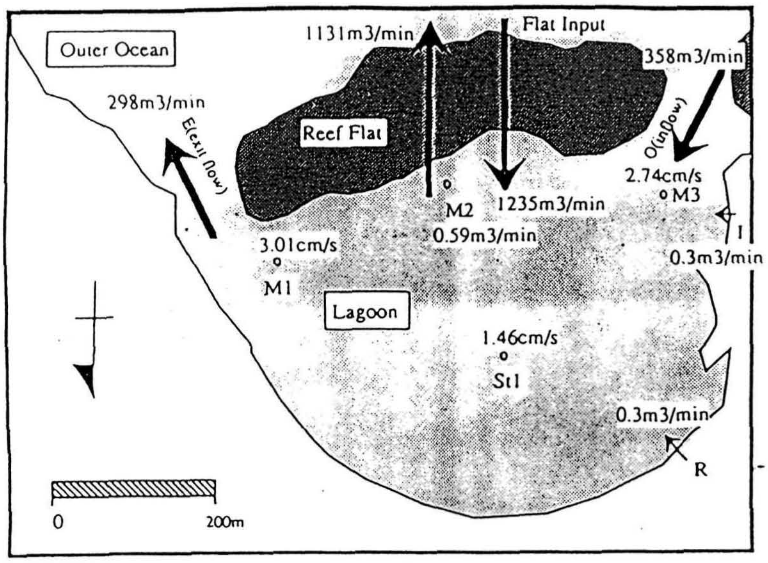

Fig. 1 Samplingstation in Bora-Bay at Miyako Islandand water flow (Flow rate was calculated by S. Kraines)

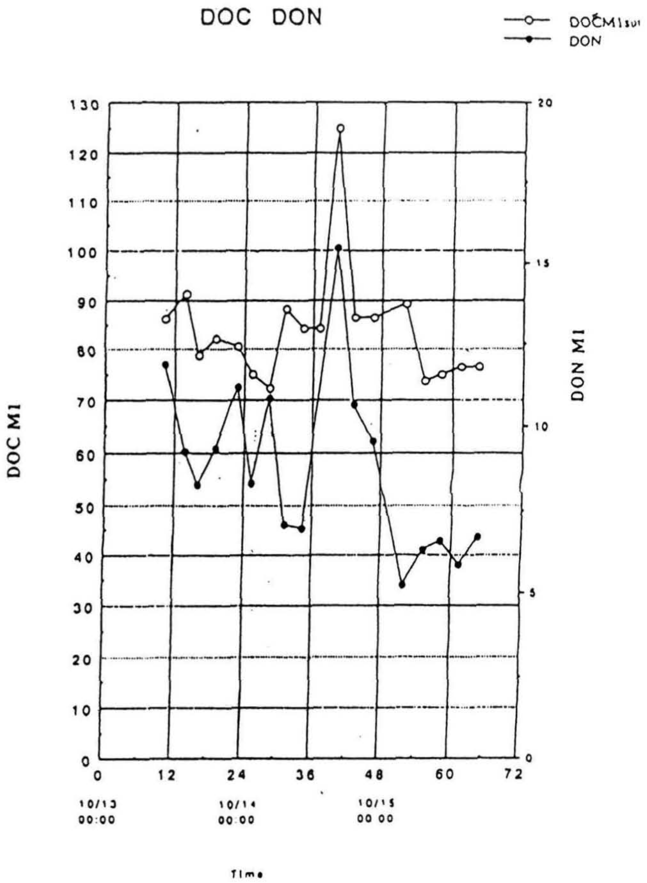

Fig.2 The temporalchange of DOC and DON concentrationsi n coral reef waters i n Oct., 1993

and nitrogen using a N/C analyzer(Sumigraph NC-90A). Inorganic nitrogen compounds were determined using conventional methods in oceanography. The location of water sampling and the general flow of water masses inside the coral reef at Bora Bay are shown in Fig.1. Water flow at Bora Bay is characterized by a mixing of open ocean water circulated in a constant direction clockwise from west (M-3) to east (M-1) and passing over the reef-flat with the tidal cycle, and underground water supplied by run-off from the west shore and from the sediment. The water depth varies from 2.5 to 4.5 m throughout a tidal cycle.

3. PREVIOUS IDEA ON CARBON AND NITROGEN FLUXES IN CORAL REEFS

The simplest and oldest theory of calcification is that photosynthetic removal of carbon dioxide displaces the carbonate equilibrium in coral reef water. Thus, photosynthesis is intimately associated with calcification in coral reef [4], and organic material may play a role in CO_2 release by calcification. However, little is known about the fate of organic matter produced by or released from organisms in coral reefs. Rate of gross primary organic production (P) and respiration (R) are obtained by calculations based on the daily variation of dissolved oxygen concentrations or TCO_2 concentrations [5][6]. According to Crossland et al., net productivity is close to zero (0 ± 0.7 g C m^{-2} d^{-1}) , and they concluded that organic carbon metabolism plays only a minor role in the carbon fluxes in coral reefs and the reef excess production is approximately 0.05% of the net CO_2 fixation rate of the global ocean [5] integrated the air/sea CO_2 fluxes over 24-h and showed that the reef ecosystem they studied is a source of CO_2 to the atmosphere [6]. However the role of organic matter fluxes in coral reefs is underevaluated. It is thought that organic production only promotes cacification. But the question remains, does organic matter accumulate in coral reefs? Figure 3 shows a schematic diagram of carbon and nitrigen cycles in coral reefs. This figure shows that organic matter produced within coral reefs are exported into the open ocean by water exchange, because the concentration of organic matterin the coral reefis thought to be much higher in coral reefs than those of open ocean [7]. But the recycling of organic matter in coral reef waters is ignored.

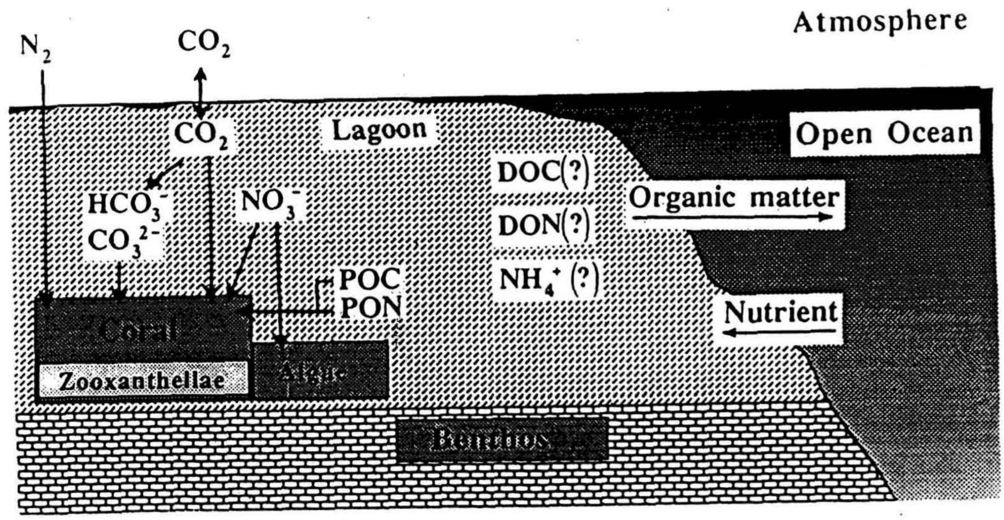

Fig. 3 The previous idea of carbon and nitrogen cycling in coral reefs

4. TEMPORAL CHANGE OF ORGANIC MATTERS CONCENTRATIONS IN CORAL REEF WATERS AT MIYAKO ISLANDS

The temporal change in concentrations of dissolved organic carbon (**DOC**) and nitrogen (**DON**) in October '93 is shown in Fig. 2. The concentrations of **DOC and DON** range from 72 μmolC l^{-1} to 125 μmolC l^{-1} for carbon and 5 μmolN l^{-1} to 16 μmolN l^{-1} for nitrogen, which are lower and have a larger variation than those of open oceanic water (average value : 93 umolC l^{-1} for carbon and 10.5 μmolN l^{-1} for nitrogen). The concentrations of particulate organic carbon (**POC**) and nitrogen (**PON**) including living organisms are from 11 μmolC l^{-1} to 17 μmolC l^{-1} for carbon and 1.8 μmolN l^{-1} to 2 μmolN l^{-1} for nitrogen, which are as the same order of magnitude as those of the open ocean. In general, coral reefs are areas of higher productivity, therefore it is expected that more organic matter would be produced making organic matter concentration greater in coral reef waters. However, this is not the case. There is no regular diel variation in the temporal change of **DOC and DON** concentrations. The highest concentrations of **DOC and DON** during the period of observation are found near noon of October 14, and this high value declined rapidly.

We can also see that high **DOC and DON** concentrations sometimes appear at night. The change of **POC and PON** concentrations also does not have a strong correaltion with photosynthesis. These results suggest that most of the appearance of organic matter in coral reef waters is not correlated directly to primary production, but rather is correlated to the release of secondary production by heterotrophic organisms such as coral and benthos. Unusually high concentrations of **DOC and DON** might be due to the active release by disturbed coral as well as the reduced water volume by the low tide. We calculated the **C/N ratio** from the concentrations of **DOC and DON** (Fig.4). The **C/N ratio** in organic matter is also not constant. Lower **C/N ratios** of about 8 appear mostly at night time. Although the **C/N ratio** in mucus released by coral is little known, Ducklow estimated that the C/N ratio of mucus is about 4.8 [8]. If we take this value, it appears that coral releases mucus during the night time, and the main origin of **DOC and DON** is from the oxidation of mucus in water or sediments by the microbes or dissolution of mucus in water. The higher **C/N ratio** during the day time might be due to photosynthesis by algae, because the C/N ratio of algae is about 18.

Assuming that all organic matter is supplied only from mucus, algae and the open ocean, at night time:

$$(C/N)obs. = f4\,(C/N)mucus + f5\,(C/N)open \qquad (1)$$
$$f4 + f5 = 1$$

and at day time:

$$(C/N)obs. = f1\,(c/N)mucus + f2\,(C/N)\,algae + f3\,(C/N)\,open \qquad (2)$$
$$f1 + f2 + f3 = 1$$

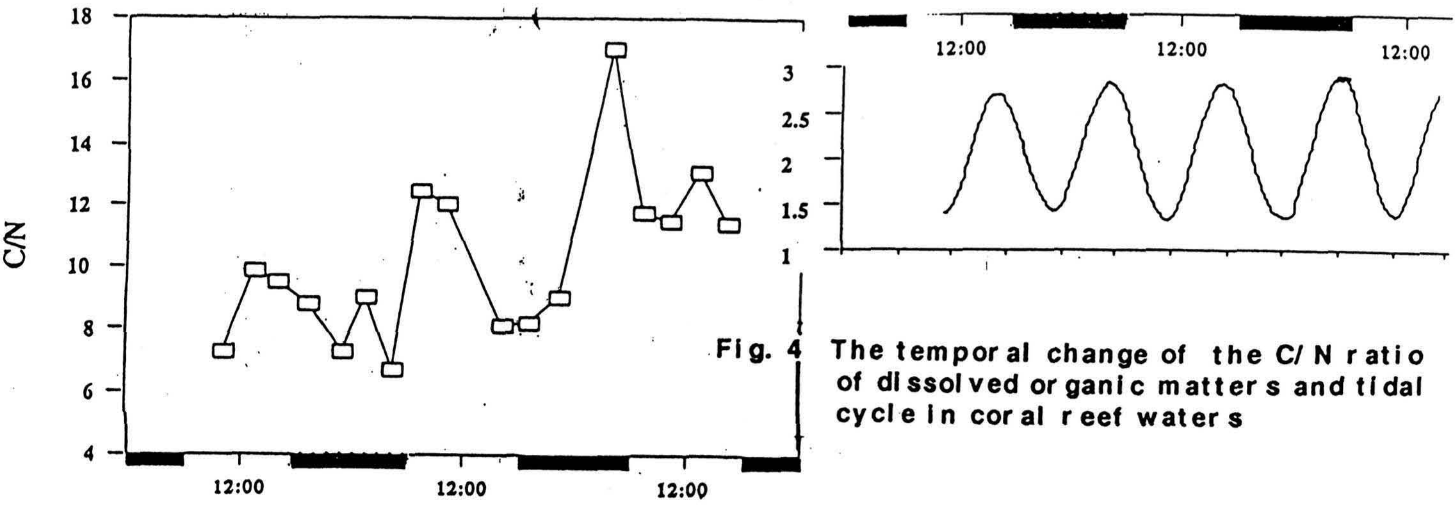

Fig. 4 The temporal change of the C/N ratio of dissolved organic matters and tidal cycle in coral reef waters

Using the values of (C/N)obs. =7.8, (C/N)mucus =4.8, (C/N)open = 9, and then f4 is 0.28. At night time, about 30% of dissolved organic matter in the water column originates from mucus possibly by increased coral sensitivity. We also calculated the balance between production and consumption for dissolved organic matter from the temporal change of concentrations and **C/N ratio**.

The consumption is in excess of the balance of dissolved organic matters in water column. 7 umolC l^{-1} for carbon and 1.1umolN l^{-1} for nitrogen per hour are required for coral growth. Inorganic nitrogen compounds are almost balanced when ammonium is considered as nitrogen source.

5. CONCLUSION

The lower concentration of dissolved organic matter (**DOM**) in coral reef waters suggests that the concentration of **DOM** is not indirect propotion to the primary organic production and that DOM also disappears quickly from the coral reef waters through uptake by the heterotrophic organisms.Also there is an imbalance between rate of change of inorganic species (Kraines, unpublished data) and organic species, the amount of change of organic matter being smaller than that of TCO_2. This also suggests that most of the organic matter produced remains stored in living organisms [9]. Thus, it appears less likely that carbon is lost by evasion to the atmosphere as CO_2 from oxidation in the micro-web and also export to the open ocean. It seems likely that biologically fixed CO_2 preserved as organic material in coral reef waters, sediments and organism living in the coral reef ecosystem

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