4. Summary and Conclusions

The aim of this study was to assess the relative importance of the biological processes that intervene in nitrogen recycling within a coral reef ecosystem and quantify the rates of nitrogen flux through these pathways in space and time.

The specific objectives were:

1) To study spatial and temporal variations of ambient nitrogenous nutrient concentrations.

2) To assess the relative importance of each of these nutrients to reef primary producers and seasonal changes in it - assimilation by phytoplankton.

3) To measure nitrogen flux through some bacterial pathways (e.g. nitrification) over seasonal scales and relate it with the availability of each nitrogenous nutrient.

The study was carried out at the Kalpeni atoll (10° N and 73° E) in the Lakshdweep group of islands. A total of 12 stations in the lagoon and two stations in the open sea were chosen for seasonal studies. The study period extended from January 1993 to March 1995.

Salient observations

Ambient nitrogen concentrations

1. The dissolved inorganic and organic nitrogen concentrations, tested with ANOVA, showed significant variations among all the three seasons and between monsoonal
and non-monsoonal months. PON concentrations showed significant variations only between monsoon and non-monsoon months.

2. Range and average concentrations of nitrate in the three seasons showed a decreasing trend, from relatively higher values in the monsoon months through low values in the post-monsoon to the lowest values in the pre-monsoon period.

3. The nitrite values did not show such a trend as with nitrate. In monsoon months (July and August) the levels often fell below the limits of detection, in contrast to the higher values of NO₃ in this season.

4. Changes of ammonium and urea showed same seasonal patterns. Higher concentrations of these two nutrients were observed in the post-monsoon season followed by the pre-monsoon and remarkably low concentrations in the monsoon months.

5. Urea concentrations were higher than those of ammonium throughout the study period.

6. The dissolved organic nitrogen (DON) values were several orders of magnitude higher than those of dissolved inorganic nitrogen (DIN). The DON was the largest fraction, accounting for 74% of the total dissolved nitrogen. Seasonal changes of DON were interesting in that they contrasted with most of the DIN nutrients, except nitrate.

7. Changes of the concentrations of particulate organic nitrogen (PON) showed a close similarity to those of ammonium and urea. However, ANOVA tests showed that
the variations between the three seasons were not significant. Variations significant at 95% level were observed only between the monsoon and non-monsoon months.

8. Chlorophyll values also changed in a trend similar to that of ammonium and urea. The variations between the three seasons and in the nonmonsoon months were highly significant (99% level) as against the small variations in the PON values.

_Uptake studies_

1. The seasonal changes in the uptake rates of NO₃, NH₄ and urea show clearly lower values in monsoon months, higher values in post-monsoon and intermediate values in pre-monsoon.

2. The correlation co-efficients between ambient concentrations and specific and absolute uptake rates were significant (95% and 99% levels) in all instances except in the case of absolute uptake of urea in relation to it's concentration in the lagoon.

3. Ammonium was the preferred form for uptake followed by urea and nitrate.

4. Regenerated production (ammonium and urea uptake) was responsible for more than 90% of the total N uptake.

5. In the lagoon, ammonium is the form clearly preferred over urea and nitrate at any time, with urea ranking next in importance. While, this order is generally valid for the eastern station, in the post monsoon months nitrate is taken up at more or less equal rates along with ammonium and urea.
Nitrification studies

1. There is a definite seasonality in the rates, with high values in pre-monsoon months, followed by a sharp decrease in monsoon, and a subsequent increase in post-monsoon season.

2. The rates were generally high compared to those from the other ecosystems (Kaplan, 1983).

3. The rates measured in this study for surface sediments (33.6 nmol g⁻¹ h⁻¹) are higher than those of Corredor and Capone (1985).

Oceanic uptake studies

1. Nutrient concentrations were remarkably high in the euphotic zone near the reef in comparison with the surrounding oligotrophic waters.

2. Diel changes of N nutrients at stations outside the reef showed low concentrations at flood tide and increased levels during ebb tide.

3. Average nitrogen uptake rates were 37.3, 8.5 and 1.8 nmol l⁻¹ h⁻¹ respectively for ammonium, urea and nitrate. Among these ammonia and urea rates are an order of magnitude greater than those reported for other oceanic waters.

4. The distribution of nitrate and ammonium at several transect stations across the Kalpani lagoon showed a distinct increase in the values over live coral patches.

Conclusions

1. The findings suggest that there is sufficient new nitrogen input (NO₃⁻) in the monsoon months. While the post-monsoon season is supported mainly by regenerative
flux (Ammonium and Urea), there is no indication of either new or regenerative fluxes in the pre-monsoon season.

2. The heterotrophic biomass build-up is not interfered even at low concentrations of available nitrogen. The more or less equal values of PON in the pre and post-monsoon are indicative of this.

3. It is concluded that the nitrogen uptake is dependent not only on the substrate availability but also on the prevailing weather conditions.

4. Nitrification studies in the water column and sediment lead to conclude that, the production of N in one form and its transformation to another, proceeds at appreciable rates in the coral reef ecosystems.

5. The nutrient flux studies provide evidence for the fact that reefs export particulate organic matter and dissolved inorganics in measurable quantities.

6. Comparison of phytoplankton growth rates calculated as N-supported with those from literature (Wafar et al., 1986) showed that most of the ammonium and urea uptake would rather be due to heterotrophic utilization. This along with high microbial biomass and heterotrophic activity observed in other studies in the Lakshadweep atolls (Chandramohan & Ramaiah, 1987) suggest a predominance of heterotrophy over autotrophy in nitrogen flux in reef waters.