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ALGAL NITROGEN FIXATION IN THE NORTHWESTERN PART OF THE ARABIAN GULF

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ABSTRACT

Nitrogen fixation and cell counts of blue-green algae and diatoms in the northwestern area of the Arabian Gulf were assayed during the period, 7-20 November, 1984. Spatial variations indicated that the maximum rate of nitrogen fixation and count of blue-green algae were found in Qatari water. The minimum values, on the other hand, were observed at the area of oil pipe lines off Saudi Arabian coast. Blue-green algae were represented mainly by *Trichodesmium* spp. and *Anabaena* spp.. In Kuwaiti water, where diatoms dominated the phytoplankton, nitrogen fixation was of moderate values. Experiments on diurnal variation of nitrogen fixation were conducted. Fixation in the dark was only up to 15% of that measured during the day light time.

INTRODUCTION

Nitrogen fixation, a biological process conducted by blue-green algae, is considered among the most important biological processes in the oceans (Stewart, 1971 & 1975, Goering and Parker, 1972 and Fogg, 1978). In the Arabian Gulf, as in other marine environments, nitrogen is accepted to be the limiting nutrient for the primary productivity, thus, nitrogen fixation could be one of the sources of nitrogen input in these habitats. No previous work has attempted to assay this process in the Gulf region.

The present paper gives data on nitrogen fixation occurred by blue-green algae in the part of the Arabian Gulf extending from Kuwait to Qatar (Fig. 1). Diurnal variations of the nitrogen fixation activity at one of the stations was followed.

MATERIALS AND METHODS

Thirteen hydrographic stations were sampled by the Qatar university R.V. "Mukhtabar Al-Bihar", in the study area, during the period 7-20 November, 1984.

Water and phytoplankton samples were collected from the uppermost 50 cm depth by a two litre PVC Niskin bottle.

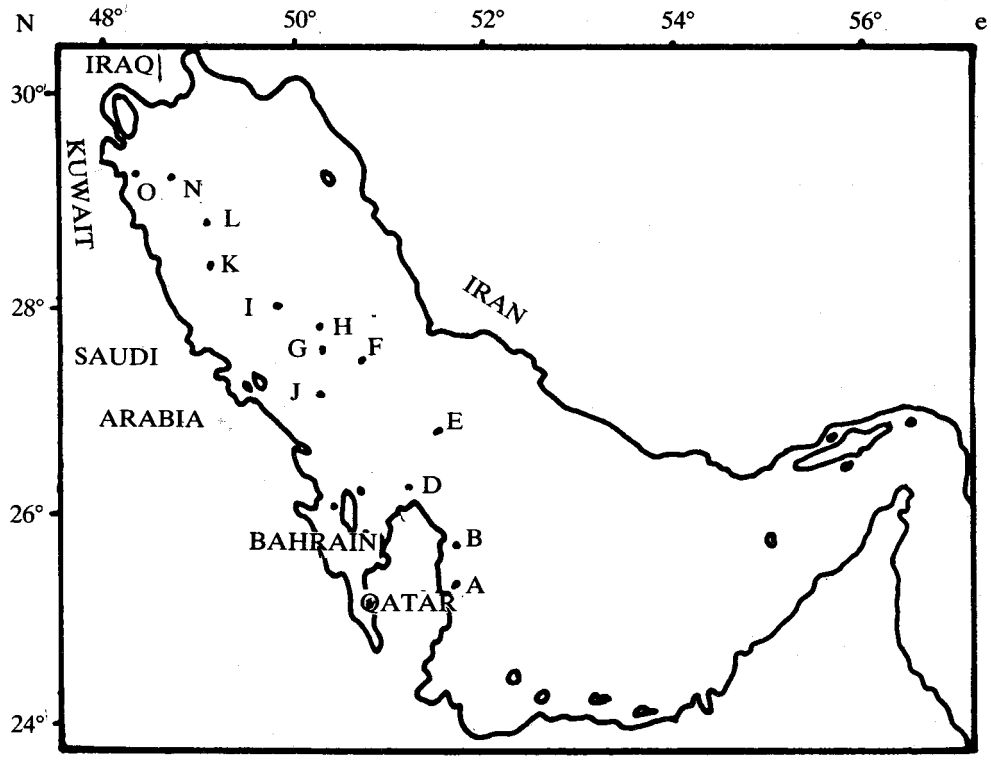

Fig. 1: Locations of the sampling stations in the Northwest Arabian Gulf, Nov. 1984.

Nitrogen fixation was measured by acetylene reduction technique (Stewart et al., 1971) modified by Horne and Goldman (1972). 40 ml of seawater was introduced into a 125 ml bottle and incubated for 3h. during the light time in flowing seawater on deck. A varian 2700 gas chromatograph with a 2m Porapak R column was used. The carrier gas was nitrogen and flow rate was 40 ml min^{-1} at temperature of 60°C.

For the estimation of the phytoplankton density, 1 litre of the seawater was collected and kept in a plastic bottle from each station. The samples were preserved by adding 4% neutralized formalin and were left for a few days to allow the settling of the planktonic organisms. They were then concentrated to 50 ml and the standing crop of the blue greens and diatoms was obtained by counting and averaging 3 counts in each sample.

The diurnal variation of the nitrogen fixation rate was also studied. The experiments were conducted at station B throughout 24h. at time intervals of 3h..

RESULTS

The values of the algal nitrogen fixation and the cell count of both blue green algae and diatoms at the sampled stations are shown in Fig. 2. The densities of the blue green algae showed in Fig. 2, do not include the count of *Richelia* inhabiting *Rhizosolenia*.

The maximum algal activity ($6.4\times10^{-2}\mu$MN l^{-1} h^{-1}) was measured at station B, while the minimum activity (0.4×10^{-2} μM N 1^{-1} h^{-1}) was observed at Sts. E and F. Nitrogen fixation in the Kuwaiti water ranged between 1.8×10^{-2} and 3.9×10^{-2} μM N 1^{-1} h^{-1}.

Table 1

Diurnal variations of nitrogen fixation rate in μM N 1^{-1} h^{-1}.

LIGHT		DARK	
time	N. fix. rate	time	N. fix. rate
6 — 9	6.4×10^{-2}	18 — 21	0.90×10^{-2}
15 — 18	5.0×10^{-2}	21 — 24	0.63×10^{-2}

The maximum count of the blue green algae (19476 cells 1^{-1}) was found at station B, while the minimum count (475 cells 1^{-1}) was recorded at station F. Blue green algae were represented mainly by *Trichodesmium* spp. and *Anabaena* spp. It is to be noted that *Anabaena* sp. was found with variable numbers in the whole Gulf

region by Al-Kaisi (1976). There were no blue-green algae detected at stations E, G, H and O.

Ammonia concentrations ranged between 0.02 and 0.22 μg at N l^{-1}, nitrate ranged from 0.09 and 1.27 μg at N l^{-1}, dissolved oxygen varied between 0.19 and 0.24 mMole l^{-1} and pH values fluctuated around 8.2 ± 0.1.

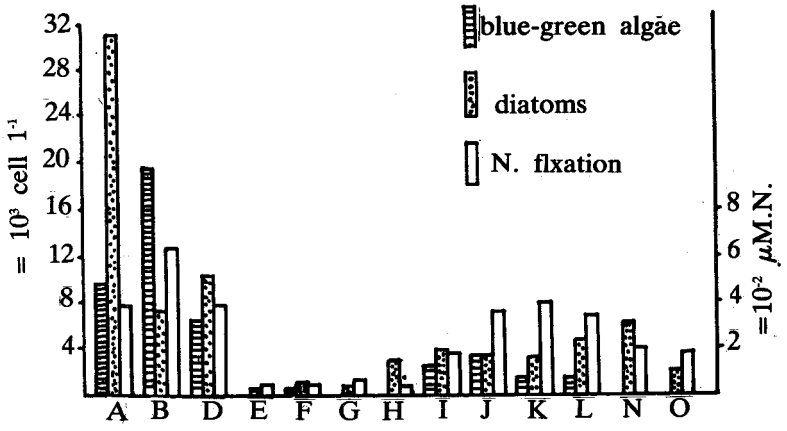

Fig. 2: Distribution of the nitrogen fixation and the cell count of blue green algae and diatoms at different stations.

The diurnal pattern of algal activity in fixing nitrogen in the Gulf waters is shown in table 1. Morning time (6-9 am) seemed to be the time for maximal activity (6.4×10^{-2} μM N l^{-1} h^{-1}). In the afternoon (3-6 pm) the rate was 5×10^{-2} μMN l^{-1} h^{-1}. Relatively low algal activity was measured during the dark (0.63×10^{-2} μM N l^{-1} h^{-1}). Unfortunately, no count of the phytoplankton was made concurrently to the samples collected for the study of diurnal variation of the nitrogen fixation. However, the number of the blue green cells at station B was 20700 cells l^{-1}.

DISCUSSION

It is evident that combined nitrogen is generally the main limiting nutrient for the primary productivity in oceanic water (Thomas, 1969 and Conover, 1975). The ability to fix nitrogen would therefore be expected to be of great biological advantage in the Gulf water. From the present data, the Gulf water could be a favourable medium for the blue green algae to flourish and to be quite active in nitrogen fixation. Concentrations of ammonia and nitrate never exceed 2 μg at N

1^{-1} and may not reach levels which would inhibit the process of nitrogen fixation; Horne (1977) and others found that ammonia inhibits nitrogen fixation at concentration above 8 μg at N 1^{-1}. The alkaline reaction of the Gulf water (pH=8.2) is very suitable for nitrogen fixers; Brock (1973) stated that alkaline media of pH about 8 favour blue-green algal activity.

From the present data the rate of nitrogen fixed per cell in Qatari water was calculated to be 46 Pg N cell^{-1}h^{-1}. A value of 70 pg N cell^{-1} h^{-1} was calculated from data given by Hanson and Gundersen (1976) for bacterial nitrogen fixation in Kaneohe Bay, Hawaiian Islands. In contrast, Carpenter and McCarthy (1975) gave a value of 0.2 pg N cell^{-1} h^{-1} in Sargasso Sea. However, it was stated that rates of nitrogen fixation per cell in the Caribean Sea were much greater than those reported in the Sargasso Sea (Carpenter & McCarthy, 1975). These differences in the rate of nitrogen fixation in different areas could be related to the different environmental conditions.

It is to be noted that the rate of nitrogen fixation in the study area was relatively higher than what might be expected from the densities of blue green algae given in Fig. 2. Other participating planktonic Cyanophyceae could be, therefore expected to contribute to the high rate of nitrogen fixation. A total cell number of *Richelia* spp. (up to 2000 cell 1^{-1}) was recorded by Dorgham (unpublished data) inside the cells of the diatom *Rhizosolenia*. Fogg (1978) pointed to the role of the *Richelia* inhabiting diatoms in the nitrogen fixation. Furthermore, tropical waters are characterized by the presence of picoplankton. It seems that both *Richelia* spp. and blue-green picoplankton are likely agents responsible with other blue-greens for the high rate of nitrogen fixation measured in the present study.

A very good correlation was found between the algal quantity and the amount of the nitrogen fixed. Maximum activity was measured at the northern part of Qatari water, which coincides fairly with the maximum cell count of the blue-green algae. The minimum activity and minimum cell count, on the other hand, were found at the area off oil pipe lines in Saudi water, which reflects the effect of oil pollution. El Samra *et al* (1986) observed high values of dissolved hydrocarbons (546.4 ppb) in this area.

Nitrogen fixation activity in the Kuwaiti water seemed to be due to the *Richelia* spp. found in diatoms and to blue-green picoplankton rather than other blue-green algae, as the latter were not detected in that area.

The present study indicates that nitrogen fixation is light dependent. The dark fixation (during night) ranged between 0.63×10^{-2} and 0.9×10^{-2} μM N 1^{-1} h^{-1}, which are 10-15% of the rate in the light. It was found by Goering and Parker (1972) that dark fixation in the Indian Ocean is only 10% of that in the light.

Estimation of the role of nitrogen fixation in the nitrogen budget of the Arabian Gulf is of great importance in studying its firtility. This needs further detailed studies especially on the diurnal variations of the process. The contribution of nitrogen fixation to the nitrogen budget in the Gulf water, could be roughly estimated from the present data to be ranged between 0.4 and 6.3 kg N km^{-2} day^{-1}. This estimation indicates that the process of nitrogen fixation is a considerable source of combined nitrogen in the Gulf water. Estimation of nitrogen fixation by *Trichodesmium* spp. in the world oceans (Carpenter, 1983) indicated that the Indian Ocean had the highest annual rate of nitrogen fixation among the oceans. Mague *et al* (1974) showed that the rate was 0.8 kg km^{-2} day^{-1} in the northern Pacific Ocean and the nitrogen fixation provides up to 30% of the daily nitrogen requirement of the standing crop of the phytoplankton in this area. In contrast, Goering and Parker (1972) calculated rate of 300 kg N km^{-2} day^{-1} for a shallow tropical seagrass community, and Wiebe *et al* (1975) found average rate of 180 kg N km^{-2} day^{-1} on algal reef flats in the Marshal Islands.

In conclusion, studies on nitrogen fixation all over the world stress the importance of this process, especially, in tropical seas and oceans.

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التثبيت الطحلبي للنيتروجين في الجزء الشمالي الغربي من الخليج العربي

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و محمد درغام

في الفترة من ٧ إلى ٢٠ نوفمبر ١٩٨٤ أجريت دراسة على تثبيت النيتروجين في مياه الجزء الشمالي الغربي من الخليج العربي بواسطة الطحالب الخضراء المزرقة .

تبين من النتائج أن أعلى قيم لتثبيت النيتروجين وعدد الطحالب المزرقة وجدت في المياه القطرية ، بينما أقل قيم لهذه المتغيرات لوحظت في المنطقة التي تمر فيها خطوط أنابيب البترول أمام شواطىء المملكة العربية السعودية . ومن ناحية أخرى ساد نوعان من الطحالب الخضراء المزرقة كلا المنطقتين هما : *Trichodesmium sp., Anabaena sp.*

في مياه الكويت كان تثبيت النيتروجين ذا قيم متوسطة في الوقت الذي سادت فيه الدياتومات مجموعات العوالق النباتية .

بالاضافة إلى ذلك تمت دراسة تغير تثبيت النيتروجين في أوقات اليوم المختلفة عند احدى المحطات حيث تبين أن قيمة التثبيت أثناء الظلام يصل إلى ١٥٪ فقط من ذلك الذي يحدث خلال ساعات النهار .

ومن مجموع النتائج أمكن حساب ميزانية النيتروجين في مياه الخليج وكميته التي يمكن أن تدخل إليه عن طريق تثبيت النيتروجين بواسطة الطحالب الخضراء المزروقة .