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Heterotrophic activity and bacterial growth in a tropical lake (Lake Xolotlán, Managua, Nicaragua)

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Introduction

There have been relatively few studies focused on microbial dynamics in tropical lakes (see PAYNE 1986). High sustained primary production is a common phenomenon of these lakes, even when ambient inorganic nutrient levels are low or below detection levels (e.g. GANF & VINER 1973) implying rapid mineral cycling. Decomposition and mineralization of detritus must be very rapid to maintain such high nutrient turnover rates, suggesting high microbial heterotrophic production.

Lake Xolotlán is a shallow polymictic tropical lake. It is very eutrophic and has a high and constant phytoplankton production (ERIKSON et al. 1991). The trophic structure of Lake Xolotlán appears to be strongly dominated by primary producers and decomposers whereas consumers such as zooplankton, zoobenthos and fish seem to be suppressed (CIRA 1987). The lake also receives a heavy load of organic matter with the sewage from the city of Managua. Nutrient cycling is rapid as inorganic nutrients accumulate only at low levels (ERIKSON, PUM & VAMMEN in prep.). The decomposition and mineralization of organic matter from microbial activity must therefore be very effective and play a key role in total lake metabolism.

In these first studies of the microbial activity of Lake Xolotlán we assessed bacterial abundance and bacterial production during an intensive sampling period at the peak of the rainy season in October 1988. We concentrated on assessing short-term (daily) and diurnal changes in bacterial activity. A full description of the seasonal variation in primary production, size-fractionated respiration, and bacterial production as well as a comparison of the leucine and thymidine incorporation methods for estimating bacterial production will be discussed elsewhere (ERIKSON et al. in prep., BELL et al. in prep.).

Material and methods

Samples were taken from depths of 0.5 m and 3 m at station 1 (max depth 5 m – in the southern basin, 3.5 km in front of the coast of the city of Managua) and from 0.5, 3, and 10 m at station 7 (max depth 15 m – in the center of the northern basin) at 10 a.m. on 4, 6, 8 October and for a 24 hour period every fourth hour on 10 – 11 October.

Subsamples for enumeration of bacteria were placed in plastic 20 ml scintillation vials containing 2 ml of sterile formaldehyde (2 % final concentration). Bacteria were enumerated on 0.2 μm pore-sized Nuclepore filters using acridine orange stain and epifluorescence microscopy Zeiss filters KP 490, Rfl 510, LP 520) according to BELL et al. (1983). The presence of cyanobacteria after sonication was estimated from autofluorescence (Zeiss filters BP 546, Rfl 500, LP 590) in epifluorescence microscopy (BOSTROM et al. 1989).

Bacterial heterotrophic production was estimated from the incorporation of (^{3}H)thymidine (BELL et al. 1983). Triplicate samples plus a formaldehyde-killed blank were incubated in situ in 20 ml plastic scintillation vials with 25 nM of (^{3}H) thymidine (50 Ci · mmol^{-1}) for 30 minutes. The optimal thymidine concentration and incubation time were chosen after extensive preliminary experiments whereby thymidine was added over a range of 5 – 50 nM for 10 – 60 minutes. The vials were placed horizontally in plexiglas tubes that could be closed at the ends and hung at discrete depths (0.5, 3, 10 m). Incubations were stopped by adding one ml of formaldehyde (2 % final concentration). Subsamples of 5 ml were extracted in the laboratory by adding ice-cold 40 % trichloroacetic acid (TCA) to a final concentration of 5 %. Filtration was performed with 0.45 μm membrane filters (Schleicher & Schuell) using a 10-place Teflon filtration unit equipped with stainless steel funnels to ensure that the samples remained at <5 °C during filtration. The funnels were then removed and the filters rinsed 5 times with 1 ml portions of ice-cold 5 % TCA followed by 5 rinses with ice-cold 80 % ethanol. The filters were dried then transported to Uppsala, Sweden for analysis on an LKB Model 1217 liquid scintillation counter. Thymidine incorporation as pmol · l^{-1} · h^{-1} was converted to units of carbon with the conversion factors of 30 fgC · cell^{-1} (average of BRATBAK & DUNDAS 1984 and LEE & FUHRMAN 1987) and 2 · 10^9 cells produced · nanomole^{-1} incorporated thymidine (BELL et al. 1983, BELL & KUPARINEN 1984, SMITS & RIEMANN 1988, CHIN-LEO & KIRCHMAN 1988).

Thymidine incorporation was also measured in the three months (July, August, September) before the October sampling period.

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Results and discussion

The abundance of bacterioplankton was extremely high: $20-25 \cdot 10^6 \cdot ml^{-1}$. Little is known about total bacterial concentrations in tropical lakes but concentrations as high as those in Lake Xolotlán have been reported for the Varzea Lakes in Central Amazonia: $4.2-15.6 \cdot 10^6\, ml^{-1}$ in the dry season (Rai 1979).

Rates of [^{3}H]-thymidine incorporation were higher at the shallow station 1 (see Fig. 1) in the 4 months of July to October ranging from 85–104 pmol $\cdot l^{-1} \cdot h^{-1}$ in station 1 and 50–80 pmol $\cdot l^{-1} \cdot h^{-1}$ in station 7 during morning sampling (10 a.m.).

The difference between the two stations was observed also during the 4 day sampling period (see Fig. 2) in October where thymidine incorporation rates ranged from 80–92 pmol $\cdot l^{-1} \cdot h^{-1}$ at station 1 and 44–117 pmol $\cdot l^{-1} \cdot h^{-1}$ at station 7. On 10 October incorporation rates were equal at the two stations. Strong winds on 8–9 October caused a stronger resuspension of sediments which could have contributed to the higher production at the deeper station 7.

Bacterial activity was almost always equal throughout the water column (see Figs. 2 and 3) in contrast to temperate stratified lakes, where activity is nearly always highest in the epilimnion of both eutrophic (e.g. Bell et al. 1983) and oligotrophic (Scavia et al. 1987) lakes.

A diurnal study at station 7 of thymidine incorporation was carried out from 11 a.m. on 10 October until 10 a.m. on 11 October. At 11 a.m. thymidine incorporation (see Fig. 3) was highest at 10 meters (136 pmol $\cdot l^{-1} \cdot h^{-1}$) supporting the hypothesis of higher production due to stronger resuspension of sediments. The rate of incorporation of thymidine in the surface waters increased throughout the day likely in response to algal photosynthesis and consequent release of organic compounds by the algae. After 10 p.m. rates of thymidine incorporation decreased throughout the water column and the strongest decrease was noted between 2:30 a.m. and 6 a.m.

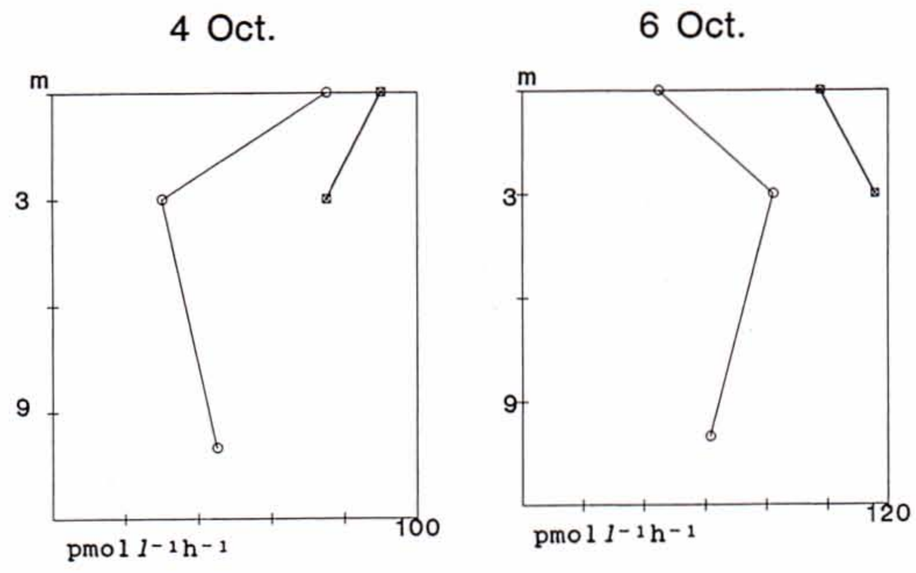

Fig. 2. [^{3}H]-Thymidine incorporation in Lake Xolotlán during 4 days in October, 1988; measurements were performed on samples in 0 and 3 m depths at Station 1 ——□ and in 0, 3, 10 m at Station 7 ——○.

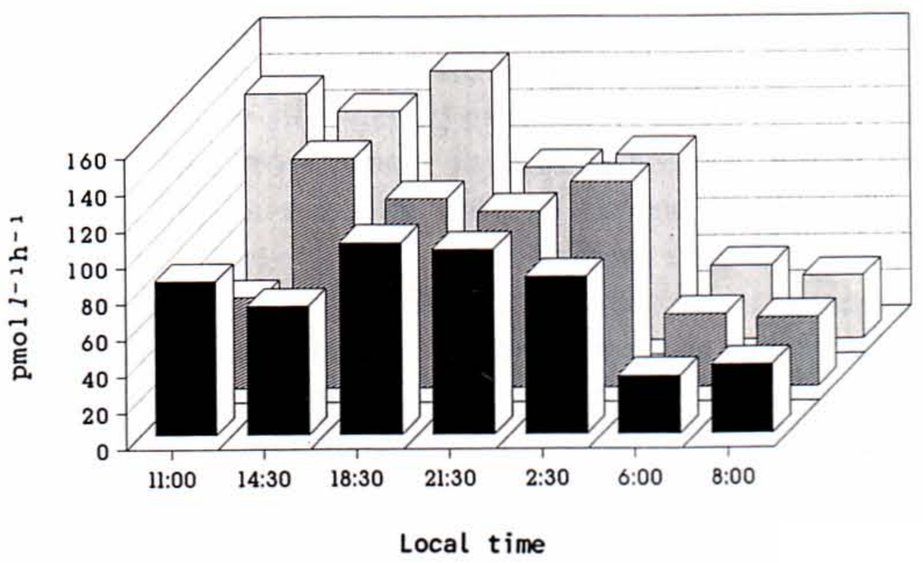

Fig. 3. [^{3}H7-Thymidine incorporation in Lake Xolotlán during diurnal sampling on 10–11 October, 1988; black: 0 m, dark grey: 3 m, light grey: 10 m.

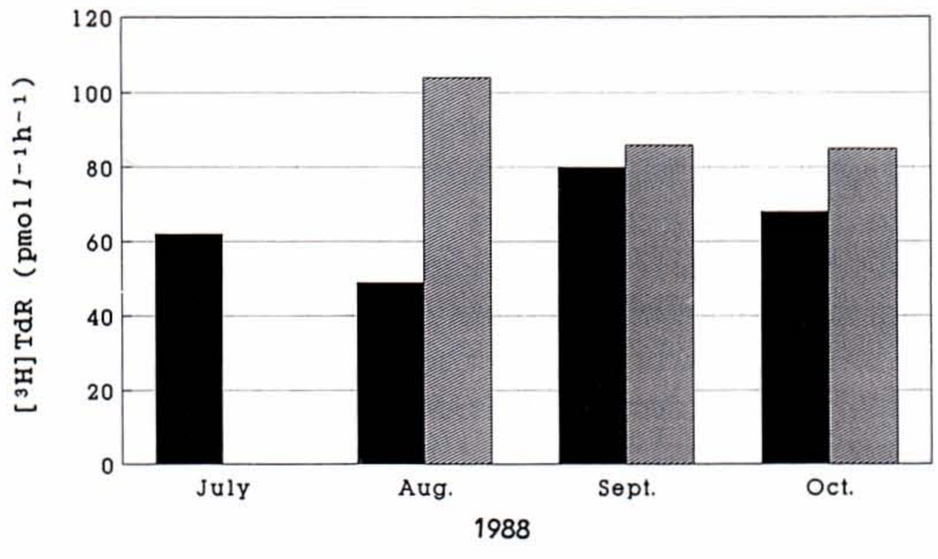

Fig. 1. [^{3}H]-Thymidine incorporation in Lake Xolotlán during four months of the rainy season, 1988; measurements were performed on surface samples at 10 a.m.; black: Station 7, shaded: Station 1.

Summary

[^{3}H]-thymidine incorporation was consistently high in the 4 monthly sampling dates of the rainy season averaging 91 pmol · l^{-1} · h^{-1} at station 1 and 65 pmol · l^{-1} · h^{-1} at station 7. The bacterial production varied however almost three-fold in the 4 morning sampling dates at station 7 in October due to the influence of the wind on sediments. Thymidine incorporation varied by a factor of 3 during the 24 hour diurnal sampling.

Bacterial production (thymidine incorporation converted to units of carbon) averaged ca. 840 mg C · m^{-2} · day^{-1} in Lake Xolotlán. In a recent evaluation of temperate lakes (Cole et al. 1988) the highest production reported was 580 mg C · m^{-2} · day^{-1}. This high areal production of Lake Xolotlán may be partly due to the polymictic character of the lake and other properties of tropical lakes in general, i.e. constant high temperature, efficient nutrient cycling, and also by high and constant organic loading from the city of Managua.

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