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Da cooperação entre Max-Planck-Institut für Limnologie, Abteilung Tropenökologie, Plön, Alemanha, e Instituto Nacional de Pesquisas da Amazônia, Manaus–Amazonas, Brasil

Microbiology of Central Amazon Lakes

by

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Introduction

The importance of microorganisms for metabolic processes in the aquatic habitat has long been known. Microbiology and biochemistry represent a unit. Without the knowledge of some metabolic activities and biochemical processes, the heterotrophic part of the ecosystems, especially the metabolic relationship between autotrophic and heterotrophic structures cannot be understood. One of the special features of the heterotrophic part of the ecosystem is that the processes directed by microorganisms are very fast. Microorganisms can respond to environmental changes in a matter of seconds or minutes. In contrasts to plants and animals, microorganisms are not restricted to a single metabolic type, but include various groups of chemosynthetic, photosynthetic and heterotrophic organisms.

Microorganisms often enhance the productivity of water bodies by making available to the aquatic organisms, the organic matter originally produced in the surrounding areas and transported into the water body by the movement of the water. This is certainly the case in the Amazon river system. In water bodies which have large surrounding drainage basins, the production of microorganisms at the expense of energy of allochthonous materials from land or from other water bodies can be of the same order of magnitude as autochthonous primary production by plants and can sometimes exceed it (KUZNETSOV and ROMANENKO 1966).

Secondary production of heterotrophic microorganisms is of special importance for the following reasons: (1) microorganisms are capable of attacking organic substances that cannot be utilized by animals, and (2) microorganisms produce particulate food materials from dissolved organic materials and therefore represent an important link in the natural food chain.

During secondary production, decomposition processes release the energy necessary for biosynthesis, and release also mineralized nutrients for primary production.

The difficulties in the work with the heterotrophic bacteria begin with the often discussed problem of the determination of the biomass and lack of information on the species composition of bacteria in the lake ecosystem.

Perhaps in the aquatic environment of Amazon the phytoplankton is of secondary importance as a direct source of food for the zooplankton. Even if the zooplankton in the Amazon lakes in fact lives under suboptimal conditions for long periods, other food sources must be taken into consideration. The most important must presumably be bacteria and detritus.

From the distribution pattern and bacterial structure in the aquatic ecosystem, much information may be obtained on the function of the freshwater bacteria. The study of in situ activities is probably the most important problem in the microbial ecology. At the level of microorganisms it is rate that is potentially more important than the absolute value of the biomass.

The purpose of this study was to determine the dynamics of the openwater bacteria in the Central Amazon lakes (Fig. 1) both by direct microscope count and the uptake of labelled glucose, and to investigate possible relationship between the bacterial and phytoplankton cycles.

This paper is concerned with the determination of the uptake kinetics, an approach which since its introduction by PARSONS and STRICKLAND (1962), HOBBIE and WRIGHT (1965) and WRIGHT and HOBBIE (1965, 1966), has been widely used. Three parameters relating to the function of the aquatic microflora can be computed from the uptake kinetics:

1. The theoratical maximum velocity of uptake.
2. The approximation of the natural substrate concentration.
3. The turnover time for the substrate to be completely removed from solution by the natural population present in the sample.

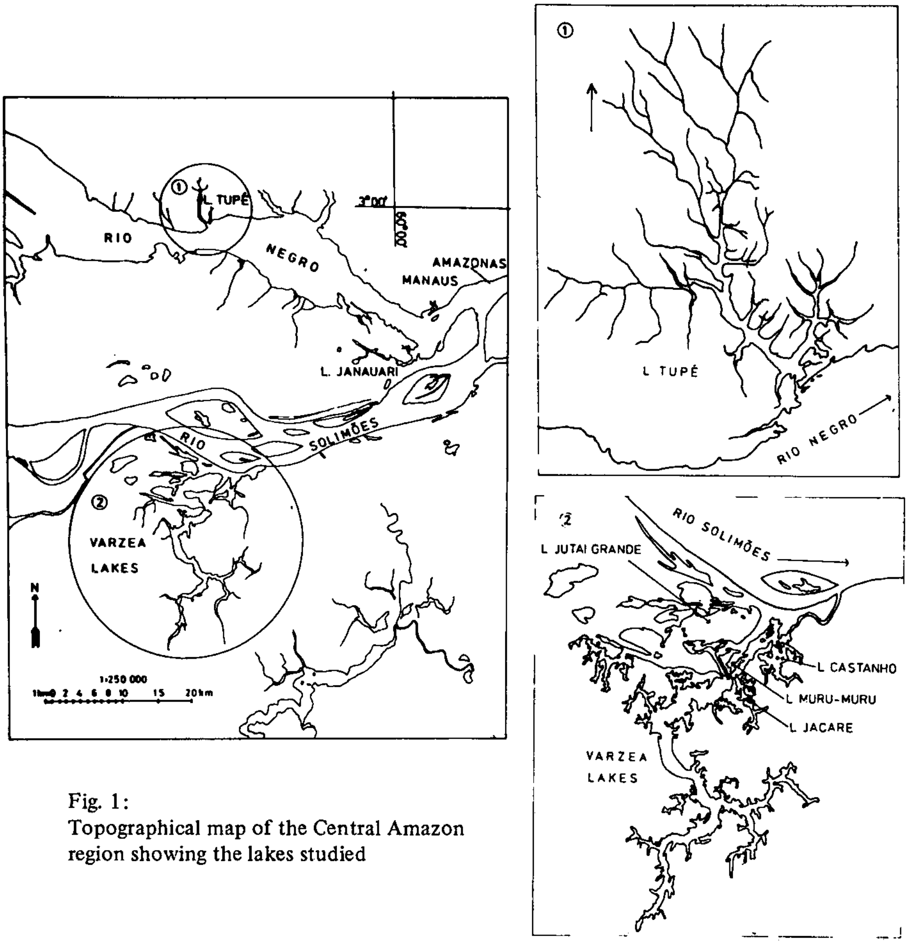

Fig. 1:
Topographical map of the Central Amazon region showing the lakes studied

Material and Methods

Water samples were collected at the middle of each lake studied (Fig. 1), with the help of an aseptic sampler (RAI - in press). All experimental work was done on board "MARUPIARA" (Barco-laboratorio do INPA), which was fitted with microbiological and 14-C measurement equipment. The samples were placed on magnetic stirrer and filtered through Sartorius membrane filters, pore size 0.8 μm. Samples were then dispensed in 50 ml aliquots into a series of 5 acid washed 120 ml glass-stoppered sterile bottles. The substrate used was glucose (UL) - 14-C (Radiochemical Centre, Amersham, England) with a specific activity of 16.7 μCi/mg glucose. The usual additions were 30, 60, 120 and 240 μg glucose with 30 μg glucose per liter (killed blank) from a 1 μCi/ml, 14-C - glucose (UL) sterile ampule. The samples and blanks were then incubated at the "in situ" temperature in the dark for 60 minutes. After incubation metabolism was immediately stopped by the addition of Lugol's acetic acid solution (NAUWERCK 1963).

All samples were then filtered on to Sartorius membrane filters (porosity 0.25 µ) and the filters were placed in a Scintillation vial containing Scintillation cocktail (15 ml of Scintillation fluid which consisted of 4.0 g 2,5 . disphenyloxazole (PPO) and 50 ml 1,4 - 2 (5 - phenyloxazolyl) - benzone (POPOP) per 1000 ml toluene) and the activity of the filters were applied in the following equation, as described by WRIGHT and HOBBIE (1965): $C \mu t/c = (Kt + Sn)/Vmax + A/Vmax$, where C is the count per minute from one µCi of 14-C glucose in the counting assembly used, µ the number of µCi added per 50 ml sample, t the incubation time (hours), c the radioactivity of the filtered organism (cpm), Kt the transport constant, which expresses the affinity of the uptake system for the substrate, Sn the natural substrate concentration (µg/l), Vmax the maximum velocity of uptake (µg/l/h) and A the added substrate concentration (µg/l). Chlorophyll-a was estimated as described in details by RAI (1978 (a)) and corrected for pheo-pigments. For the measurement of the dissolved organic carbon (DOC) water samples were filtered through GF/C Whatman Glass Fiber filters which were ignited at 520° C in advance and determination of dissolved organic carbon was performed by using the filtrate for carbon analysis with the help of a Beckman TOC analyzer, Model 915 A. Total organic carbon (TOC) was analysed directly in the samples with the help of a Beckman analyzer and the difference between the TOC and DOC was taken as particulate organic carbon (POC).

Total bacterial numbers were determined by the direct count method of Razumov (KUZNETSOV and ROMANENKO 1964). A known amount of water was filtered through sterile 50 mm diameter, 0.2 µm poresize membrane filter. The filter with bacteria was stained with erythrosin B, then dried and a known area of each filter was cut, mounted in immersion oil and placed under a coverslip. A minimum of 400 bacteria were counted 1500 x with a phase contrast light microscope. Estimation of saprobic bacterial densities were made using Standard Plate Count Agar as prescribed in the Standard Methods (1971) and incubated at 22 and 35° C, which is a measure of standardized population (GELDREICH 1965). Preliminary experiments by the author showed that incubation at 22 and 35° C gave almost similar results. Thus, for Standard Plate Counts, pour plates were incubated at 35° C for 74 hours.

Results and Discussions

Glucose Uptake Studies in Lago Tupé (Black Water Lake)

Over 95% of the experiments resulted in least square linear regression with coefficients of determination of 0.95 or greater. The results of glucose uptake determinations showed (Fig. 2) that during the increasing water level the Vmax was maintained by the natural populations at almost minimum. The maximum velocity (Vmax) and (Kt + Sn) were directly proportional since both increase or decrease in a like manner in order for the turnover time (Tt) to remain constant. But in this study Tt did not remain constant. The results reported by WETZEL (1967) showed the same trend. But ALLEN (1969) and HOBBIE (1967) did not observe such a trend. The activity of the heterotrophic population may be indicated by the magnitude of Vmax (HOBBIE 1967, and WRIGHT and HOBBIE 1966). If this is assumed, then the glucose measure activity during decreasing or low water level was greatest.

The large increases in glucose turnover time (Tt) during the high water phase were significantly different from the low water phase values, although the Vmax was almost unchanged and (Kt + Sn) did not appreciably increase during the high water period (Fig. 2). The increase in the turnover time (Tt) during the increasing water level was probably due to the changing population being brought in the lake from its catchment area, which are perhaps not of the aquatic origin.

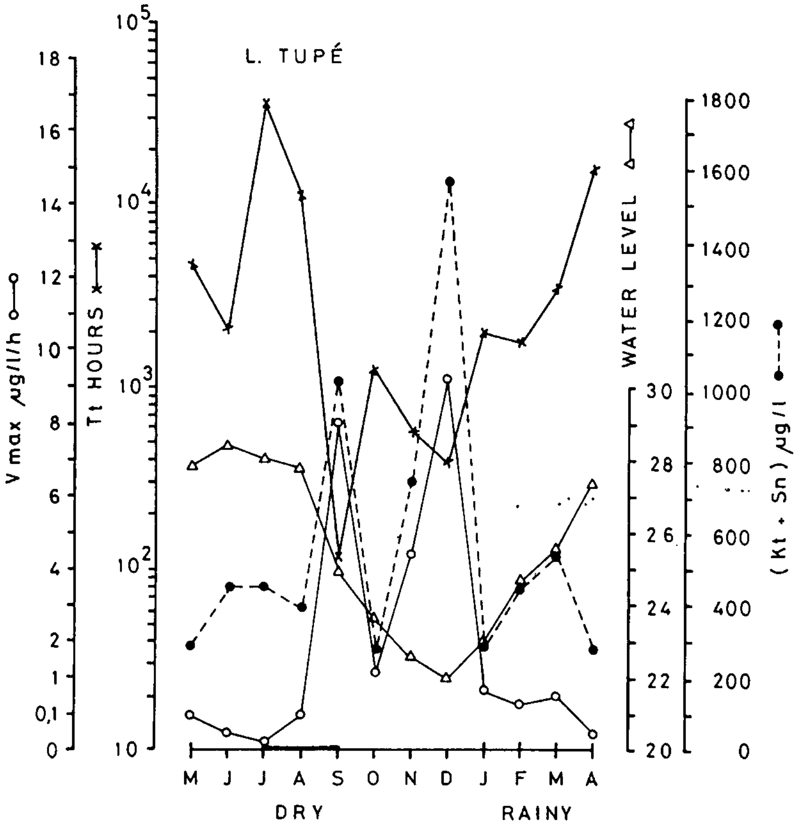

Fig. 2:
Relationship between Vmax, (Kt + Sn), Tt and water level in Lago Tupé

During high water, values of (Kt + Sn) and Vmax are low while values of Tt and bacterial numbers are high. Whereas at low water, values of (Kt + Sn) and Vmax are high and values of Tt and bacterial numbers are low (Fig. 2). The low Vmax during increasing water level in Lago Tupé means that the substrate affinity was lowest in this time of the year. During decending water level period the Vmax was higher, indicating that substrate affinity was highest in this period. Comparing measurements in aquatic environments of widely different trophic nature, the glucose uptake rates (Vmax) seems to be related to the trophic state. The more productive the water the higher the Vmax.

Increase in number of bacteria during high water period were not related to the increase in Vmax for the substrate studied (Fig. 2 and 3). This might be due to the fact that viable bacteria were being transported into the lake during floods from the catchment area of the lake. Evidently these bacteria did not play any big role for the uptake of glucose. This means that quantitative and qualitative changes in the bacterial populations can alter Vmax. The exception to this was recorded in the dry season during the months of September, November and December (Fig. 3), when increases in viable bacteria were related to increases in Vmax for glucose.

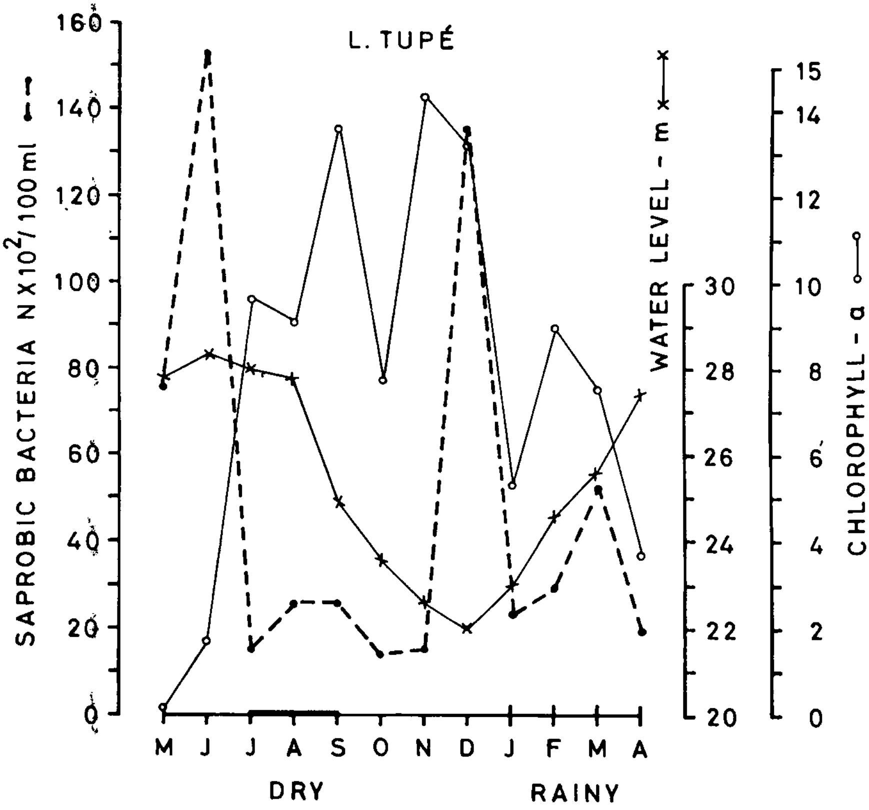

Fig. 3:
Relationship between saprobic bacteria, chlorophyll-a and water level in Lago Tupé

However, MORGAN and KALFF (1972) also found a significant correlation between total bacterial number and Vmax, but the non-uniformity of the proportionality suggested quantitative as well as qualitative changes in the bacterial population. Further, with an increased uptake rate, and high number of bacteria, an active degradation process was generally found in September, November and December in Lago Tupé.

The increase in phytoplankton (as indicated by the chlorophyll data) during the period of study (Fig. 3) was associated with increase in Vmax and (Kt + Sn), therefore, suggests that the algae in the low water period were accompanied by the release of glucose since there is no reason to asume an increase in Kt. Such a pattern was also reported by HOBBIE (1967) for the Lake Erken.

Relationship between Bacteria and Phytoplankton

In the present study it is observed that relationships between bacteria and phytoplankton are complex and tend to vary according to the lake environment, especially to the water level fluctuations. From the data (Fig. 3) it is evident that high bacterial densities coincided with high chlorophyll-a in Lago Tupé during December, February and March. The bacteria multiplied rapidly at the expense of the excretion and degradation products of algae and soluble organic compounds released by dead algae. According to GUSEVA (1952), high bacterial counts were most frequently found to coincide with large number of algae because high phytoplankton growth entails a high death rate which results in a high concentration of organic matter in the water, this, in turn accelerated the multiplication of bacteria.

Relationship between low bacterial densities and high chlorophyll-a (Fig. 3) was observed during the months of July, October and November when dominant phytoplankton groups were diatoms and dinoflagellates. Low bacterial densities might be due to the presence of silica cell wall of diatoms and cellulose cell wall of dinoflagellates, being resistant to bacterial attack. It might also be due to appreciable amounts of antibacterial substances being produced during diatom and dinoflagellate production (BURKHOLDER 1963).

Corelation between high bacterial densities and low chlorophyll-a (Fig. 3) was observed in May and June in Lago Tupé, while at this time very much detritus enters the lake ecosystem. During this period the lake develops a zone free of oxygen. Perhaps organic detritus and dead phytoplankton are bing decomposed by bacteria resulting in high oxygen demand (LUCAS and THOMAS 1972), this case a large number of bacteria to be present in the overlying water.

Low bacterial densities and low chlorophyll-a relationship were observed in October, July and April in Lago Tupé. This might have been due to toxins produced by other microorganisms (SILVEY and ROACH 1964, LÁNG 1971) or the high water level which reduces the microbiological activity in the Central Amazon lakes during this period.

There are many different relationships which exist between bacteria and phytoplankton in the Central Amazon lakes of which only a few were observed in this study. It is apparent from these relationships that further studies will gain more detailed insight into the metabolic cycling and the understanding of complex ecosystem of Amazon lakes.

Glucose Uptake Studies in Várzea Lakes

From the data on the vertical distribution of saprobic bacterial numbers during high and low water periods in the different Várzea lakes it appears that there is vertical stratification of bacteria. There is a definite increase in the number of saprobic bacteria (Tab. 1) from high to low water period in the four lakes studied. The saprobic bacteria varied between $4 \times 10^3 - 2.2 \times 10^5$/l during high water phase and $1.1 \times 10^5 - 9 \times 10^5$/l during low water phase.

The total bacterial counts, from a number of temperate oligotrophic lakes, were generally less than 5×10^8/l, while the number of bacteria in temperate eutrophic lakes were greater than 20×10^8/l (STRASKRABA and STRASKRABOVA 1969). According to MORGAN and KALFF (1972) the bacterial population in the extreme oligotrophic Char Lake varied between $0.1 - 2 \times 10^8$/l. These are one of the lowest counts reported from a freshwater system, but similar to some marine bacterial populations (JANNASCH and JONES 1959). The bacterial population of Várzea Lakes (Tab. 2) varied between $2.1 - 11.6 \times 10^8$/l during high water phase and $4.2 - 15.6 \times 10^9$/l during low water phase, whereas SCHMIDT (1969) recorded variations between $0.6 - 2.75 \times 10^9$/l for Lago do Castanho. From the number of total bacteria, these lakes could therefore, be classified as eutrophic. But this is not so if one takes into consideration the other biological and chemical parameters of the trophic state of these lakes (SCHMIDT 1973 (a) and 1973 (b) and RAI – unpublished data). It could, therefore, be misleading if only the bacterial population (Total counts) are used to classify the lakes according to their trophic state.

During the high water period in the Várzea lakes maximum glucose uptake velocities (Vmax) varied between 0.039 and 0.662 µg/l/h and during low water period Vmax varied between 1.36 and 2.944 µg/l/h (Tab. 3). This means an increase of 8 – 32 fold activity from high water period to low water period.

The heterotrophic uptake of glucose has been measured in both freshwater and marine environments of different trophic states. Vmax appears to be related to the trophic level of the habitat as indicated by phytoplankton primary production (Fig. 4) and suggests the possible use of this approach in assessing the trophic status of Várzea lakes. It might be mentioned here that according to the results of this study the Várzea lakes of the Central Amazon region are almost oligotrophic during high water period and during low water period they are quite productive (Fig. 4).

Glucose turnover rates (Tt) similarly appear to be related to the trophic level of the lakes as indicated by primary production (Fig. 3). Higher turnover rates (Tt), occuring during high water level indicate virtually no bacterial activity, but Tt of 40 - 120 hours, as reached in the Várzea lakes and Lago Tupé during the low water phase, shows a considerable turnover of organic matter.

Earlier research workers (HENRICI 1937, KUZNETSOV 1959, OVERBECK 1967, 1968, and SCHMIDT 1969) have observed that high phytoplankton biomass is followed by a rise in the heterotrophic bacterial population utilizing the organic matter produced by the algae. Other workers have noted a positive relationship between Vmax and phytoplankton abundance (HOBBIE and WRIGHT 1968, WRIGHT 1970, SEKI and HARDON 1970, HAMILTON and PRESLAN 1970). In the Várzea lakes studied, the relationship ($r = 0.963$) between Vmax and phytoplankton biomass (as measured by chlorophyll) was quite evident (Tab. 4).

Maximum numbers for viable bacteria (Tab. 1) and Vmax (Tab. 4) coincided with high values of dissolved organic and particulate organic matter (RAI – unpublished data).

Tab. 1: Vertical Distribution of Viable Bacteria* $(10^3/l)$ for Different Central Amazon Várzea Lakes in the Janauacá Region

Low Water Period (LWP) = 01.12. - 05.12.75
High Water Period (HWP) = 20.08. - 27.08.75

Depth	L. Castanho		L. Muru-Murú		L. Jacaré		L. Jutaí Grande	
m	HWP	LWP	HWP	LWP	HWP	LWP	HWP	LWP
0	88	140	38	186	64	770	32	400
1	43	420	30	900	92	111	50	360
2	28	300	51	–	27	–	114	–
3	34		94		45		34	
4	26		220		49		60	
5	41		56		32		15	
6	42		73		78		21	
7	28		47		47		31	
8	20		37		48		12	
9	–		42		38		29	
10	36		56		51		4	
11	18		–		–		–	
Σ/m^3	0.404	0.860	0.744	1.086	0.571	0.881	0.391	0.760

* Standard Plate Count (aerobic and facultative anaerobic heterotrophic bacteria) at 35 ± 0.5° C for 74 ± hours.

Tab. 2: Vertical Distribution of Bacterial Numbers $(10^7/l)$ for Different Central Amazon Várzea Lakes in the Janauacá Region

Low Water Period (LWP) = 01.12. - 05.12.75
High Water Period (HWP) = 20.08. - 27.08.75

Depth	L. Castanho		L. Muru-Murú		L. Jacaré		L. Jutaí Grande	
m	HWP	LWP	HWP	LWP	HWP	LWP	HWP	LWP
0	23.3	418.5	45.7	1450.5	33.2	1078.4	81.7	1021.9
1	20.8	1083.9	44.4	1562.5	61.8	1254.8	61.8	1012.6
2	36.0	788.9	45.9		45.0		67.7	
3	56.8		56.8		61.2		63.4	
4	54.3		65.5		55.3		71.8	
5	52.2		61.8		68.6		73.0	
6	56.5		56.5		94.7		82.0	
7	62.4		40.1		116.2		95.4	
8	63.9		58.4		99.1		84.8	
9	65.5		53.4		73.9		76.7	
10	31.9		43.5		75.2		–	
Σ/m^3	0.524	2.291	0.572	3.013	0.784	2.333	0.758	2.035

Tab. 3: Vertical Distribution of Vmax (μg/l/h) for Different Central Amazon Várzea Lakes in the Janauacá Region

Low Water Period (LWP) = 01.12. - 05.12.75
High Water Period (HWP) = 20.08. - 27.08.75

Depth	L. Castanho		L. Muru-Murú		L. Jacaré		L. Jutaí Grande	
m	HWP	LWP	HWP	LWP	HWP	LWP	HWP	LWP
0	0.091	2.944	0.131	1.967	0.262	1.715	0.063	–
1	0.127	2.461	0.115	2.460	0.082	–	0.169	1.369
2	0.140	2.908	0.085	–	0.662	–	0.054	–
3	0.123		0.074		–		0.039	
4	–		0.086		–		–	
5	0.071		–		0.138		0.045	
6	–		–		–		–	
7	0.068		0.062		0.256		–	
8	–		–		–		–	
9	0.058		–		0.192		–	
10	–		0.225		–		–	

Tab. 4: Vertical Distribution of Chlorophyll–a (μg/l) for Different Central Amazon Várzea Lakes in the Janauacá Region

Low Water Period (LWP) = 01.12. - 05.12.75
High Water Period (HWP) = 20.08. - 27.08.75

Depth	L. Castanho		L. Muru-Murú		L. Jacaré		L. Jutaí Grande	
m	HWP	LWP	HWP	LWP	HWP	LWP	HWP	LWP
0	1.74	22.96	2.62	81.60	12.57	32.26	1.60	19.14
1	1.74	25.15	1.45	91.85	13.30	29.52	1.53	22.42
2	2.62	34.99	1.23	–	13.30	–	1.89	–
3	2.62	–	1.53	–	6.19	–	1.31	–
4	1.82	–	1.16	–	4.37	–	0.72	–
5	1.89	–	2.91	–	2.55	–	0.65	
6	4.44		1.09		2.84		0.72	
7	17.13		0.72		9.54		0.87	
8	25.15		0.58		29.52		1.16	
9	24.05		2.25		28.95		2.77	
10	14.39		7.14		–		10.02	
11	14.76		–		–		–	
Σ	112,0	83,1	22,7	173,5	123,0	61,8	23,2	41,6

This could indicate a relation between microbial activity (excretion and decomposition), and organic matter associated with the large phytoplankton population. Whether or not this could lead to an increase in the concentration of natural substrate was not possible to evaluate in this study.

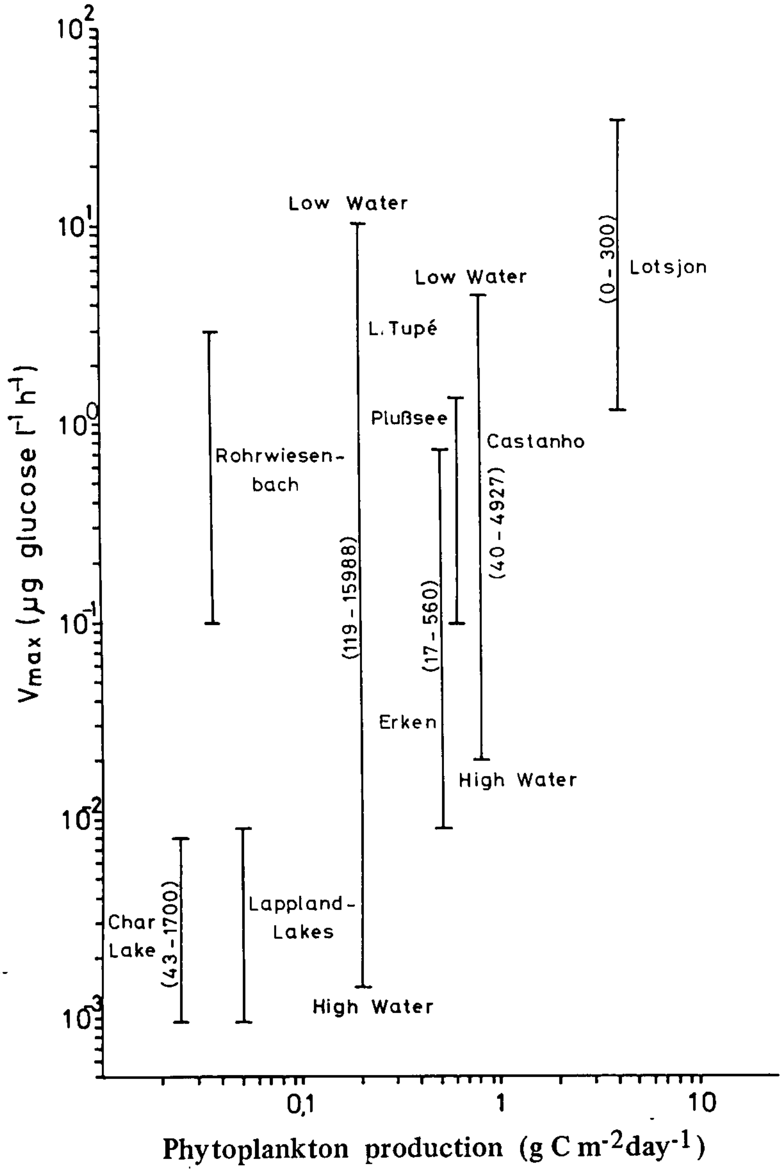

Fig. 4:
Seasonal range in maximum uptake velocity (Vmax) of glucose versus average daily primary production in several lakes. Turnover time in brackets.

The identity of the main bulk of compounds in the pool of dissolved organic carbon has been previously shown to be due to organic carbon other than monocarbohydrates (STABEL 1977). If this should be so for the DOC in the Várzea lakes, then the turnover time (Tt) determined using glucose may overestimate the true velocity of uptake (Vmax) by the bacteria, because larger turnover times (Tt) often follow more complicated molecules compared with simpler molecules like glucose.

The glucose turnover time (Tt) ranged between 189 and 4927 hours during high water and between 40 and 101 during low water period (Tab. 5). The turnover time (Tt) also appears to be related to the trophy of the Várzea lakes. During high water period the Tt values for glucose were as high as those found by SEKI et al. (1972, 1975) in extremely oligotrophic waters of Pacific Ocean, Japan and Philippine Sea, while during low water period turnover rates (Tt) were as low as those found in the eutrophic lakes of the temperate region (MORGAN and KALFF 1972, OVERBECK 1975, FRANCISCO 1971, DÜSING 1973). Relative shorter Tt of 40 - 101 hours (Tab. 5), especially during low water period show how intensively the chemo-organotrophic mineralization of organic matter takes place in the Amazon Várzea lakes (upto 48 fold increase in physiological activity of bacterial populations). There was an tendency towards a decreasing turnover-time in the low water phase. At the same time standing crops as shown by chlorophyll-a measurements increased. Thus increased mineralization of the organic matter induced primary production and increased particulate organic carbon (POC). It should, however, also be mentioned that the underwater light regime imporves considerably in the Várzea lakes, during the low water phase, and this could also influence the primary production (SCHMIDT 1973 (a)).

From the data (Tab. 1, 2 and 5) it is quite evident that Tt is low when ever bacterial density is low this means that change in bacterial numbers can account for the change in Tt. The slow turnover rates obtained may be because the substrate present is difficult to degrade, or the bacteria are in some sort of resting state for most of the time and/or their activity is inhibited by the organic matter present. The data show that the bacteria are able to induce transport mechanism during the low water period. This might be due to the change in the substrate and thus qualitative and quantitative change in the microbial population. This means that the heterotrophic bacteria in Amazon are not closely coupled to their ever changing environment (water level fluctuations) and on the other hand bacteria get well adapted, only during low water period, to chemo-organotrophic utilization of organic matter. This shows that they are opportunists waiting for favorable conditions (low water period) or a brust of phytoplankton photosynthesis to resume activity (HOBBIE 1976).

Vertical pattern in the natural substrate concentration (Kt + Sn) could be discerned in all the lakes studied (Tab. 6), but during high water level the estimated values for (Kt + Sn) ranged from 21.1 to 456.3 μg/l and during low water the natural substrate concentration fluctuated between 103.5 and 246 μg/l glucose. These studies have confirmed that generally there are large amounts of the dissolved organic pool turning over slowly, especially during high water period. But in the temperate lakes it was found that there is a small but active portion of the dissolved organic carbon pool turning over every few hours (HOBBIE 1976). This shows that temperate lakes and the lakes of the Central Amazon region are basically very different. The large values of natural substrate (Tab. 6) are prob-

Tab. 5: Vertical Distribution of Turnover Time (Tt/h) for Different Central Amazon Várzea Lakes in the Janauacá Region

Low Water Period (LWP) = 01.12. - 05.12.75
High Water Period (HWP) = 20.08. - 27.08.75

Depth	L. Castanho		L. Muru-Murú		L. Jacaré		L. Jutaí Grande	
m	HWP	LWP	HWP	LWP	HWP	LWP	HWP	LWP
0	401	40	643	101	1123	62	930	–
1	368	44	261	99	4927	–	2360	75
2	189	40	441	–	484	–	1632	–
3	204		284		–		1354	
4	–		435		–		–	
5	350		–		3085		787	
6	–		–		–		–	
7	1268		500		1659		–	
8	–		–		–		–	
9	447		–		1348		–	
10	–		989		–		–	

Tab. 6: Vertical Distribution of Kt + Sn (μg/l) for Different Central Amazon Várzea Lakes in the Janauacá Region

Low Water Period (LWP) = 01.12. - 05.12.75
High Water Period (HWP) = 20.08. - 27.08.75

Depth	L. Castanho		L. Muru-Murú		L. Jacaré		L. Jutaí Grande	
m	HWP	LWP	HWP	LWP	HWP	LWP	HWP	LWP
0	36.6	118.9	90.2	199.7	295.5	106.2	60.5	–
1	46.9	111.7	23.9	246.0	377.1	–	456.3	103.5
2	26.6	122.6	38.3	–	340.1	–	88.1	
3	25.1	–	21.1	–	–		52.7	
4	–		39.4		–		–	
5	24.9		–		373.4		35.6	
6	–		–		–		–	
7	88.8		32.2		385.4		–	
8	–		–		–		–	
9	26.1		–		275.5		–	
10	–		23.11		–		–	

ably due to concentrating of the substrate by the increase in the depth of circulation much as iron is concentrated? It may also be due to the initiation of aerobic and microaerophilic conditions with a concomitant change in the nature of the population, Kt, and glucose metabolism (FRANCISCO 1971).

The two fold increase of dissolved organic carbon (Tab. 7) during low water period might be due to the high amount of refractory organic matter present at this time in these lakes. The high DOC concentration might also be due to an equilibrium reached between decomposition and accumulation of presumably unstable DOC. The allochthonous organic matter which forms the main part of the sediment in these lakes, is perhaps to some extent slowly redissolved by chemical or microbiological degradation and diffuses in the water column. Thus the increase in the DOC at low water phase might also be due to the microbial and chemical degradation and/or diffusion from the sediment to the water column much as the same way SCHMIDT (1973b) observed resuspension of total phosphate and total iron with the sediment due to wind action during low water phase in Lago Castanho while studying primary productivity. The different types of DOC (of different molecular weight) and their percentage in these lakes, characterize the lake water types and thus different types of metabolisms in the lakes studied.

Although the bacterial populations increase several fold during the low water phase, they are not able to reduce the organic matter to low concentration in the investigated waters.

Tab. 7: Vertical Distribution of Dissolved Organic Carbon (mg/l) for Different Central Amazon Lakes in the Janauacá Region

Low Water Period (LWP) = 01.12. - 05.12.75
High Water Period (HWP) = 20.08. - 27.08.75

Depth	L. Castanho		L. Muru-Murú		L. Jacaré		L. Jutaí Grande	
m	HWP	LWP	HWP	LWP	HWP	LWP	HWP	LWP
0	5.90	9.95	6.45	14.65	6.40	10.90	7.20	9.70
1	5.70	10.75	5.95		6.50	10.45	6.80	10.10
2	5.80	10.35	7.00		5.90		6.90	
3	6.05		6.05		5.90		7.20	
4	6.30		6.25		5.80		6.80	
5	6.75		6.45		6.50		6.55	
6	6.05		7.35		5.70		6.80	
7	6.40		5.95		5.90		6.45	
8	7.20		6.25		6.75		6.55	
9	7.45		6.20		7.95		7.10	
10	8.20		5.85		7.70		7.50	
11	9.30							

Summary

Heterotrophic parameters of a black water lake (Lago Tupé) and four different Várzea lakes of the Janauacá region (L. Castanho, L. Muru-Murú, L. Jacaré and L. Jutaí Grande) were studied during high and low water phases. Besides heterotrophic planktonic bacterial populations, saprobic bacterial populations, chlorophyll–a content, and dissolved organic carbon concentration were determined because of their possible relationship to chemoorganotrophy. Saprobic bacterial numbers of black water lake (L. Tupé) ranged from 2.7 to 1.3 x 10^4/l and a maximum uptake velocity (Vmax) ranged from 0.09 – 9.3 µg glucose/l/h. Várzea lakes receive water from Rio Solimões have higher bacterial numbers. The saprobic bacterial varied between 4 x 10^3 – 2.2 x 10^5 during high water phase and 1.1 – 9 x 10^5/l during low water phase. The maximum velocity of uptake (Vmax) for the Várzea lakes varied between 0.039 and 0.662 µg glucose/l/h during high water phase and 1.36 – 2.944 µg glucose/l/h during low water phase. Comparison of kinetic data from several lakes suggests a relationship between the bacterial uptake rate of glucose and phytoplankton production. Both saprobic bacterial numbers and activity in L. Tupé may be close to the minimum recorded in the freshwater environment. In the Várzea lakes studied, the relationship between Vmax and phytoplankton biomass was quite evident (r = 0.963). The total bacterial populations of Várzea lakes were very high and ranged from 2.1 – 11.6 x 10^8/l during high water phase and 4.2 – 15.6 x 10^9/l during low water phase. The dynamics of the bacteria in the Amazon lakes is characterized by high bacterial numbers, large seasonal fluctuations, and very slow turnover times (Tt) for the available organic matter. There is a good evidence that water level fluctuations is a very important ecological parameter which regulates the microbiological productivity of aquatic ecosystem in the Central Amazon lakes. Such observations were also made earlier on the primary production of algae (SCHMIDT 1973) and on the production of floating meadows (JUNK 1970).

Resumo

Estudaram-se os parámetros heterotróficos dum lago de água preta (Lago Tupé) e de quatro lagos de várzea, diferentes, da região do Janauacá (L. Castanho, L. Muru-Murú, L. Jacaré e L. Jutaí Grande) durante as estações de água alta e água baixa. Além de populações de bactérias planctônicas heterotróficas determinaram-se populações de bactérias sapróbicas, o teôr em clorofila A, e a concentração de carbôno orgânico dissolvido, tendo em vista as relações eventuais à trofia químico-orgânica. Os números de bactérias sapróbicas do lago de água preta (L. Tupé) eram entre 2.7 e 1.3 x 10^4/litro, e a velocidade máxima de absorção (Vmax) era entre 0.09 e 9.3 µg glucose/litro/hora. Lagos de várzea que recebem água do Rio Solimões apresentam números mais altos de bactérias. As bactérias sapróbicas variaram entre 4 c 10^5 durante a fase de água alta, e de 1.1 x 10^5 e 9 x 10^5 durante a fase de água baixa. A velocidade máxima de absorção (Vmax) para lagos de várzea variara entre 0.039 e 0.662 µg glucose/litro/hora durante a fase de água alta, e de 1.36 e 2.944 µg glucose/litro/hora durante a fase de água baixa. A comparação de dados cinéticos de diversos lagos sugere uma interdependência entre a quota de absorção bacteriana de glucose, e a produção de fitoplâncton. Os números de bactérias sapróbicas como a atividad delas no Lago Tupé parecem ser próximos ao mínimo constatado no meio ambiente de água doce. Nos lagos de várzea estudados, a interdependência entre Vmax e a biomassa de fitoplâncton era evidente (r = 0.963). As populações bacterianas totais de lagos de várzea eram muito altas e variaram de 2.1 a 11.6 x 10^8/l durante a fase de água alta, e de 4.2 a 15.6 x 10^9/l durante a fase de água baixa. A dinâmica das bactérias nos lagos amazônicos carateriza-se pelo alto número de bactérias, pelas grandes flutuações estacionais, e pelos tempos muito lentos de "turnover" (Tt) para as substâncias orgânicas disponiveis. Existe bôa evidência para o fato que as flutuações do nivel d'água representam um parámetro ecológico de muita importância que regula a produtividade microbiana do ecosistema aquático nos lagos da Amazônia Central. Observações no mesmo sentido fizeram-se antes sobre a produção primária de algas (SCHMIDT 1973b), e sobre a produção dos tapetes flutuantes (JUNK 1970).

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