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SEASONAL VARIATION IN THE ESTIMATED VIABLE POPULATION OF PLANKTONIC BACTERIA IN A SMALL LAKE

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Abstract : The seasonal changes and vertical distribution of viable heterotrophic bacterial population were estimated for a period of thirteen months in a small mesotrophic lake. The lake exhibited a definite thermal and oxygen gradient with increasing depth. Marked seasonality was observed with post spring (April) maxima and winter minima. Distinct relationship between bacterial population and temperature and percentage oxygen saturation was noted. The effects of pH, conductivity, dissolved oxygen, rainfall in the week preceding sample collection on bacterial population are also discussed. *Pseudomonas, Achromobacter, Bacillus* and *Flavobacterium* were common bacteria identified.

Résumé : Les variations saisonnières et la distribution verticale d'un peuplement viable de bactéries hétérotrophes ont été étudiées pendant une période de treize mois dans un petit lac mésotrophe. Ce lac présente un très net gradient de température et d'oxygène en fonction de la profondeur. On observe une saisonnalité marquée avec des maximums de printemps (avril) et des minimums d'hiver. La population bactérienne est liée d'une part à la température et d'autre part au degré de saturation en oxygène. Les effets du pH, de la conductivité, de l'oxygène dissout et de la pluie pendant la semaine précédant la récolte des échantillons sont aussi dicsutés. On a identifié les bactéries communes suivantes : *Pseudomonas, Achromobacter, Bacillus* et *Flavobacterium.*

Resumen : Los cambios estacionales y la distribución vertical de bacterias heterotróficas viables se calculó para un periodo de 13 meses en un lago pequeño mesotrófico. El lago mostró un gradiente bien definido con relación al oxígeno y a la temperatura a profundidades crecientes. Se observó una marcada estacionalidad con una máxima postprimaveral (abril) y una mínima invernal. Se notaron relaciones claras entre las poblaciones bacterianas, la temperatura y el porciento de saturación de oxígeno, se discuten los efectos de pH, conductividad, oxígeno disuelto, lluvia en la semana precedente a la toma de las muestras, en la población bacteriana. Las bacterias identificadas fueron *Pseudomonas, Achromobacter, Bacillus,* y *Flavobacterium.*

Resumo : As mudanças estacionais e a distribuição vertical de bactérias heterotróficas, foram estimadas durante um período de 13 mêses em um pequeno lago mesotrófico. O lago mostrou um gradiente térmico e de oxigênio bem definido, e relacionado com a profundidade. Uma estacionalidade bem marcada foi observada com um máximo após a primavera (Abril) e um mínimo no inverno. Relações bemmarcadas entre temperatura da água, população de bactérias e percentagem de saturação de oxigênio foram observadas. Os efeitos de pH, conductividade, oxigênio dissolvido, precipitação na população de bactérias, como resultado de variações na semana precedente à coleta são também discutidos. Pseudomonas, Achromobacter Bacillus e Flavobacterium foram as bactérias mais comuns identificadas.

Key Words : Planktonic bacteria, lake, seasonality, vertical distribution.

INTRODUCTION

The heterotrophic bacterial population constitutes important part of the freshwater community. It is responsible for nutrient release in the ecosystem enabling optimum utilization of available energy resources for proper functioning of the ecosystem. Their activity and quantitative enumeration reflect the hydrologic structure and nutrient levels in freshwater lakes (Gedlewska:Lipowa 1976). It is often difficult in natural waters to interpret the relationship between bacterial populations and other environmental factors. This is due to the fluctuations in physico-chemical characters in time and space which may very often mask the effects due to biological changes (Jones 1971).

Earlier observations (Collins 1963) have added considerably to the ecology of freshwater bacteria. Since then, a large amount of data has accumulated which relates to the effect of environmental factors on the bacterial population in natural waters. Such findings are in many cases inconsistent (Olah 1971). Further studies are needed to evaluate the effect of environmental factors on bacterial populations, particularly in the hill lakes of India where environmental factors are often far from optimum, and where such studies are lacking. In the present paper the seasonal distribution of estimated viable heterotrophic bacteria in a small lake and its relationship with certain environmental factors is reported.

Chen (1968) and Fonden (1969) observed a relationship between bacterial populations and concentrations of phosphate and nitrogen, but this was not noted in the study of Woodbridge and Garret (1969). A relationship between weather conditions and bacterial populations was established by Collins (1960, 1970) and Chen (1968), but Taylor (1940), Malchiorri-Santolori (1966) and Guthrie (1968), did not observe the same. Depth (Olah 1969; Malchiorri-Santolini 1966), temperature (Allen 1969) and dissolved oxygen concentration (DO) (Goldman *et al*, 1968) have been found to affect the bacterial population. Jones (1972) states that the decrease in temperature, DO, pH and algal density with increasing depth may be responsible for the apparent correlation of bacterial numbers with these factors.

The relationship between phytoplankton and bacterial populations is complex. Sorokin (1968), Schmidt (1969), Oberbeck and Babenzien (1964) and Overbeck (1965, 1967, 1968) while studying the vertical distribution; and Silvey and Roach (1964), Schegg (1968) and Fonden (1969) while studying seasonal distribution found positive correlations between phytoplankton and bacterial populations; on the contrary, Pataenko and Mikheeva (1969), Gerletti and Malchiorri-Santolini (1968), Goldman *et al* (1968) and Taylor have (1940) not found any direct relationship. Gunkel (1968) and Jones (1971, 1972) have reported that maximum densities of phytoplankton preceded those of bacteria.

DESCRIPTION OF THE LAKE AND METHODS

Ward lake is situated in a valley of Shillong, India (long, 91°52'N; lat. 25°34'E) at an altitude of 1350m. The slopes of the valley are covered with dense grasses and scattered trees, predominantly of pine (*Pinus kesiya* Royle). The morphometry of the lake is given in Fig. 1.

The sampling station (Fig. 1) is located 10 m from shore in water with a maximum depth of 6 m. The bottom is silt with a cover of semi-decomposed plant litter

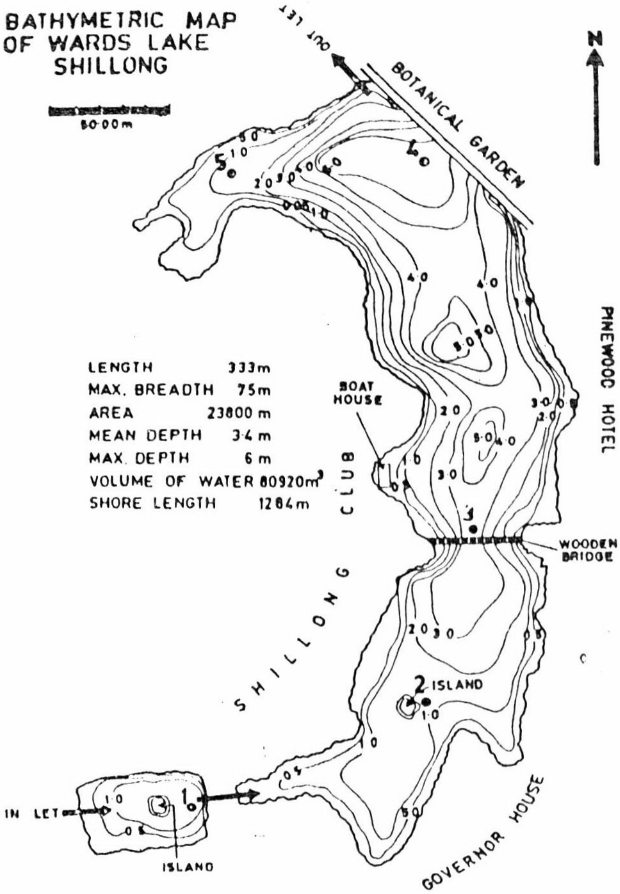

Fig. 1. Morphology of lake. Sampling station shown by solid circle.

composed mainly of pine needles. Secchi disk transparency during the study period was 1 to 1.7 m. *Chlorella* spp. and *Microcysyis* spp. dominate the phytoplankton community on which herbivorous fish and zooplankton feed.

A sizeable amount of nutrient enters the lake by surface run off and allochthonous leaf litter during fall. The total volume of the lake water remains quite constant throughout the year due to a controlled surface outflow structure.

Samples for bacteriological examination from 3 m and the bottom (6 m) were collected between 1000-1100 hours using a JZ sampler (Zobell 1941). The surface samples were collected in sterile bottles avoiding the surface film. Bottles were maintained in a dark chamber and transported to the laboratory within half an hour of sampling. Aliquots of 0.5 ml in serial dilutions were inoculated within 3 hours of sample collection to three replicates of partially dried peptone yeast extract medium. The plates were kept at 10°C for 12 hours for absorption of the aliquot and incubated at 25°C for 7 days. The plates having 30 to 300 visible colonies were counted. Composition of medium was 0.05% Bacteriological peptone (BDH); 0.05% yeast extract (Difco); and 1.5% Bacteriological agar (BDH) with adjusted pH to 7.00—7.20.

Samples for chemical analysis were collected using a 5-litre polyethylene Van Dorn bottle. Oxygen determinations were done by Winkler titration and *in-situ* temperature was recorded using a thermometer of 0.5°C accuracy. A Systronics digital pH meter (335) and Elico conductivity bridge, type CM-82 were used. The climatic data were obtained from the central seismological observatory at Meath Home, Shillong—5.

RESULTS

The results are presented in Figs. 2-5. The viable bacterial population was found to be maximum in April declining steadily to August-September. The popu-

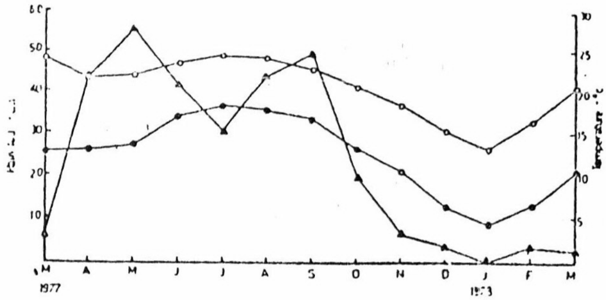

Fig. 2. Ombrothermic diagram of Shillong. Rainfall solid triangles, minimum temperatures solid circles and maximum temperature open circles.

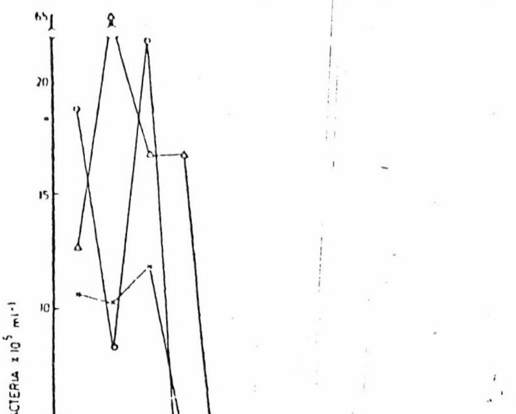

Fig. 3. Viable bacterial population. Surface open circles, mid depth open triangles and bottom Xs.

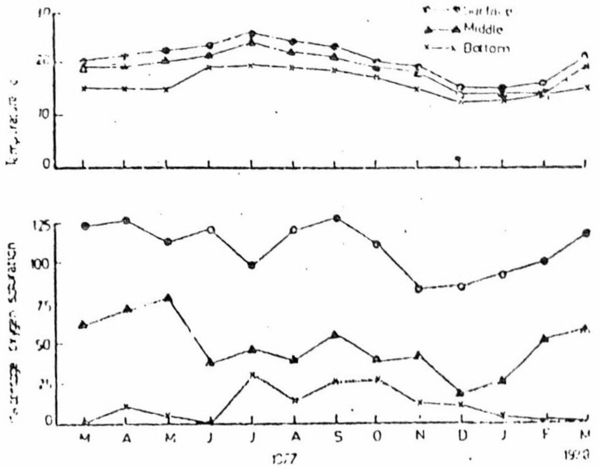

Fig. 4. Water temperature and percentage dissolved oxygen saturation.

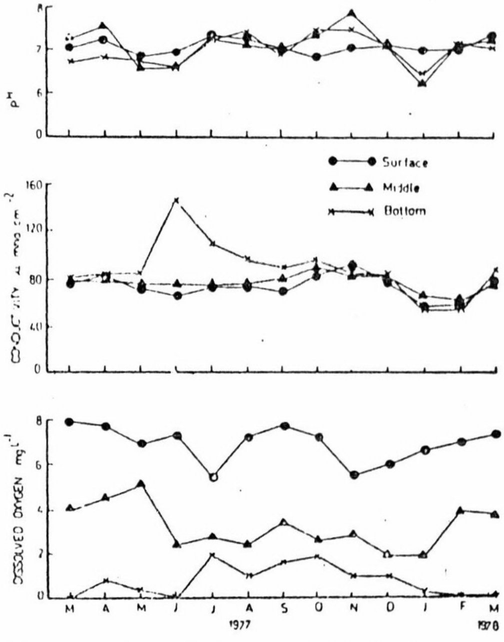

Fig. 5. pH, conductivity and dissolved oxygen.

lation showed only minor fluctuations during September, October and November and it decreased again to a minimum in December and January. A rapid thousand-fold increase in February with further increase in March was observed (Fig. 3).

The maximum water temperature occurred in the month of July and minimum in the months of December and January. The surface temperature was always higher than that at 6 m. It appears that the lake is stratified during most part of the year except January and February which is clear from the temperature and oxygen profiles (Figs. 4, 5).

Mean monthly temperatures and rainfall are shown in Fig. 2. Comparison with Fig. 3 indicates that first showers of May-June have a pronounced effect on the overall bacterial population while later rains have little effect. The gradual increase in the mean daily temperature from April to July does not result in an increase in the bacterial population (Figs. 3, 4).

Pseudomonas, *Flavobacterium*, *Bacillus* and *Achromobacter* were identified from the samples. The surface samples were always dominated by light yellow to light red coloured colonies. The bottom samples contained violet colonies of *Chromobacterium* which were usually absent from other depths.

The relationships between estimated viable bacteria at the surface, 3 m, 6 m and observed environmental variables were investigated using a simple correlation coefficient. The following variables were considered : water temperature; pH; conductivity; rainfall; dissolved oxygen; mean monthly temperature; and number of days of rain per month. A significant relationship (0.01 level) could only be determined between bacterial numbers and dissolved oxygen (including percent saturation) at the 3 meter depth.

DISCUSSION

Jones (1971) found rainfall 48 hours before sampling to be positively correlated with bacterial population in Windermere lake. Temperature and pH had a similar effect on bacterial number in Esthwaite Water. More than dozen other biotic and abiotic factors did not show statistically significant correlations with bacteria. Jones (1977) also described similar results obtained in other water bodies.

In the present study, a distinct seasonality has been observed but no definite relationship with most of the measured environmental facters could be established. This may be ascribed to a wide range of population structure of heterotrophic bacteria present at different depths and time. Owing to the low level of organization, fast growth rate and adaptations to with stand unfavourable circumstances, the overall population of viable heterotrophic bacteria may not show a response to varying conditions. This results from their fast homeostatic regulation mechanism allowing them to reach the 'maximum persistent biomass' within a short span of time. The tendency to 'persist and grow' in fluctuating environments may result in the replacement of populations, change in community structure or even in the mode of nutrition. All this may help them in adjusting to change in environmental factors.

The three sampling depths may harbour different physiological groups of bacteria belonging to the same or different taxonomic groups (Strzelczyk *et al*, 1971). It is assumed that the bottom bacteria are facultative anaerobes which produce a sizeable number of colonies when incubated aerobically. The middle waters may harbour the microaerophiles which are sensitive to the change in the dissolved oxygen concentration and possibly for this reason they were significantly correlated with DO.

The increase in bacterial population during spring (March April May) may be attributed to the first post winter rains (Fig. 2) which bring with it allochthonous bacteria and dissolved and particulate organic matter such as pine needles and pollens from the adjoining areas. The increased availability of food favours microbial multiplication which may be further promoted due to rising temperature during this period. Similar results have been reported by Andronikova and Drabkova (1972), Jannasch (1955) and Potter (1964).

The period that follows, i.e., June—August is characterized by heavy rainfall (Fig. 2) and shows a decline in bacterial populations which results from an excessive dilution of the lake water. There is further increase in temperature during this period which should favour rapid multiplication. However, this is not the case. It appears that the inoculum potential of the lake water is greatly diluted as evidenced by the small number of colonies plated from the samples (Fig. 3). This appears to be the likely explanation due to the absence of any other inhibitory factor during the course of our study, although the exact mechanism of this great reduction in bacterial population during this period remains to be investigated. Literature also supports this argument with regard to the effect of influx of water on bacterial population (Zimmerman, 1977).

Spring depletion of oxygen in the lake bottom may be attributed to microbial utilixation (Fig. 4). High conductivity in the bottom samples in the summer and reduced conductivity with onset of winter may be ascribed to the mineralization of litter in bottom which slows down with decreasing temperature and the onset of winter (Fig. 5). The range of pH observed throughout the year is well within the optimum range for the growth of freshwater bacteria and may be one of the reasons why pH did not show any significant correlation with bacterial number (Fig. 5).

The absence of correlation of bacterial population with most of the factors may be due to the fact that these organisms are not dependent upon a single factor all the year round. Also the factors may not act in isolation at a given time.

The taxonomic composition of the bacterial population is typical to oligotrophic lakes. The dominance of coloured forms in the surface samples is probably an adaptation to the light intensity.

From the above study it may be concluded that the effect of environmental changes on the estimated viable bacterial populations would be significant only if the changes were well beyond their tolerance range.

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